The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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ERRATUM

IMPORTANT NOTICE

A typographical error occurred in the article by Dr. R. I. Harris, Dr. H. S. Coulthard, and Dr. F. P. Dewar, published in the April issue. The third paragraph on page 284 should be deleted and the following paragraph should be pasted in position in your copy of the April 1952 issue.

Group II: No bacilli after streptomycin treatment. Of course many patients became free of tubercle bacilli as the result of treatment by streptomycin. In such cases no material was available to test for resistant forms at the termination of treatment. If any of these patients did harbor resistant bacilli, the clinical outcome did not appear to be impaired, as most of the lesions ended by healing. There were forty-one of these patients with "converted" lesions, representing 34.7 per cent. of the entire group. Five of these patients started with resistant bacilli carried over from previous sanatorium treatment, and yet the bacilli disappeared during streptomycin treatment.

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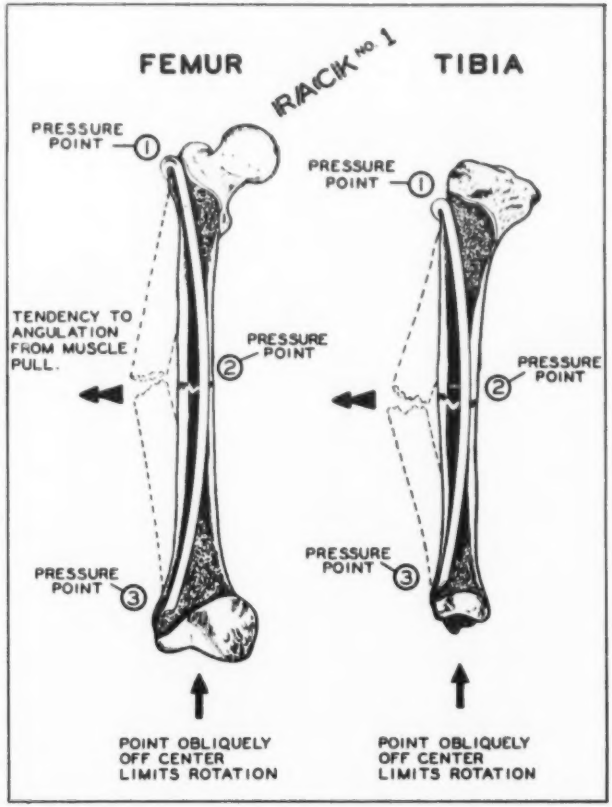

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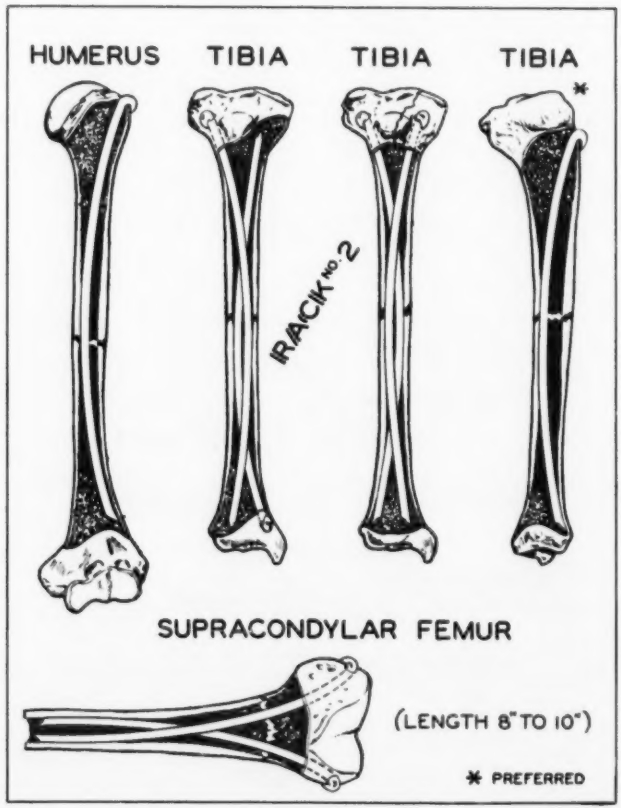

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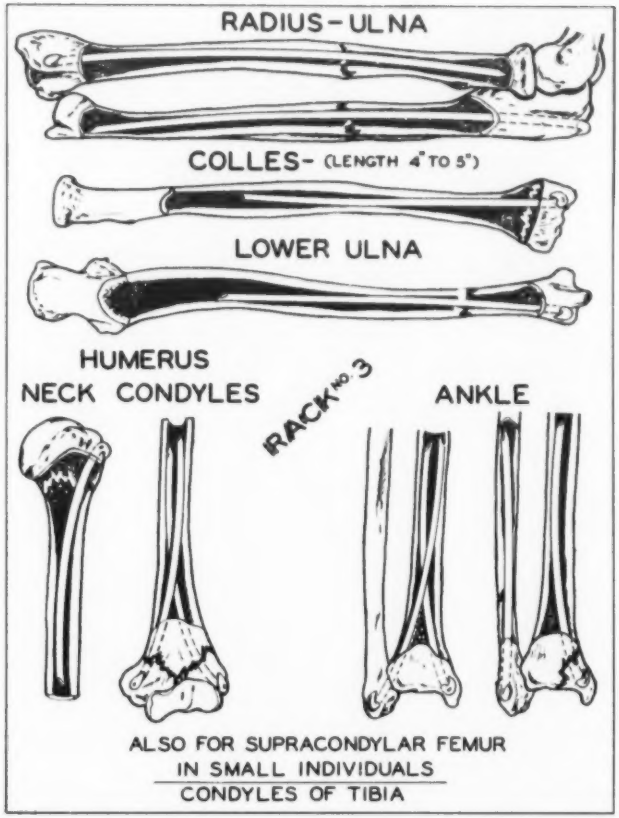

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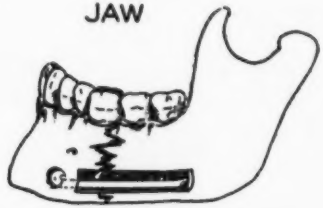

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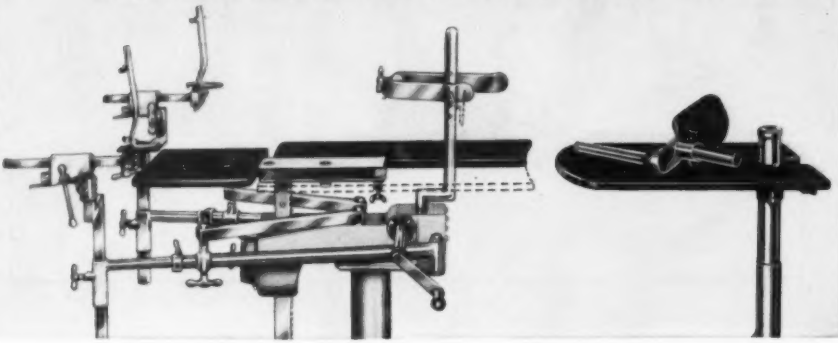

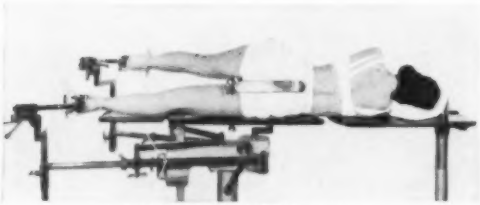

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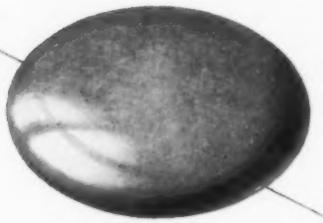

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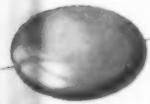

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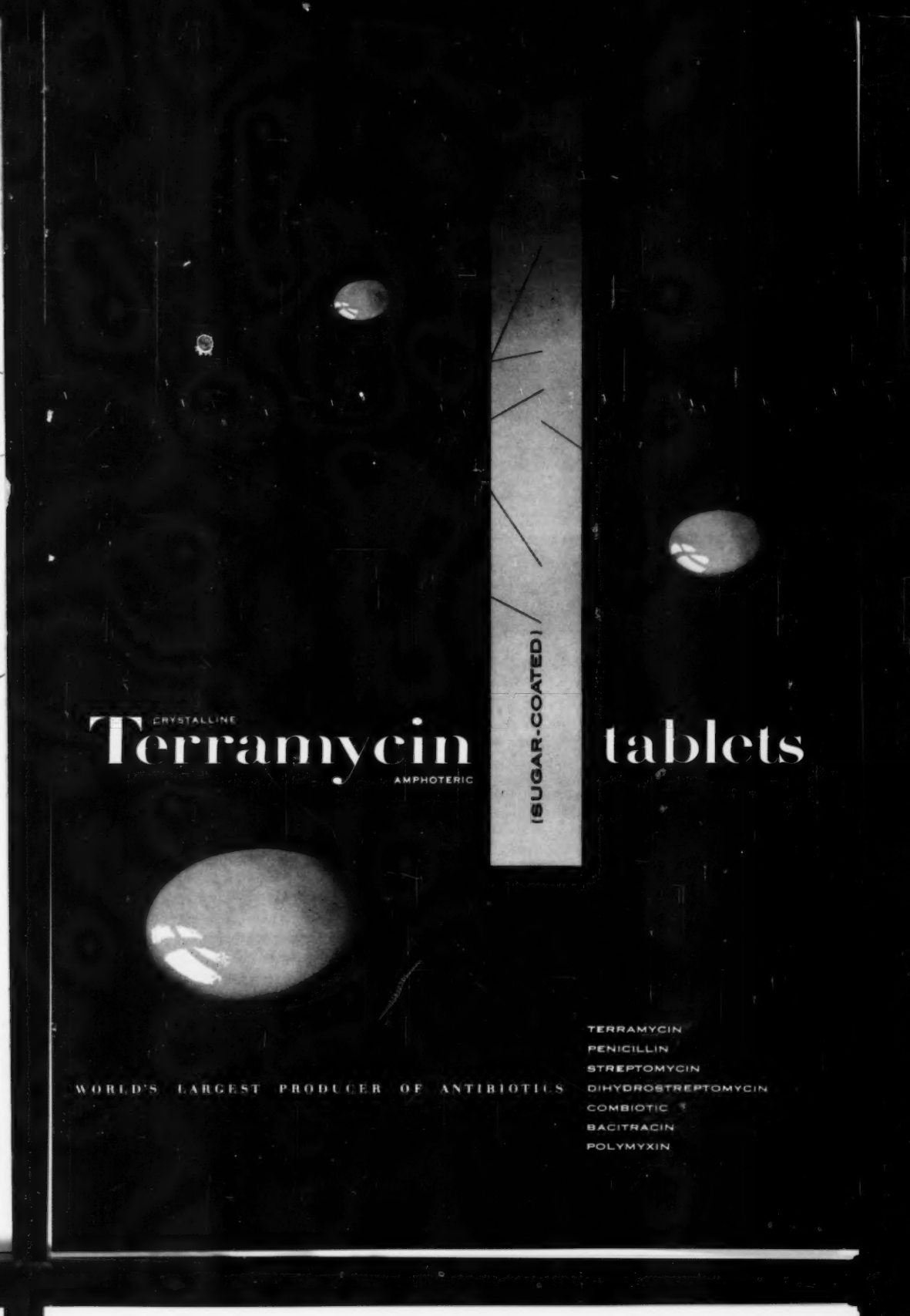
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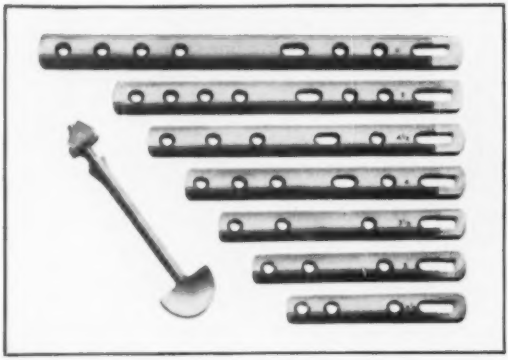

Keeping in step with the requirements and techniques of the nation's foremost surgeons are these three of the newer items in the extensive line of Vitallium Surgical Appliances. Each has been designed by the initiating surgeon to serve a definite need.

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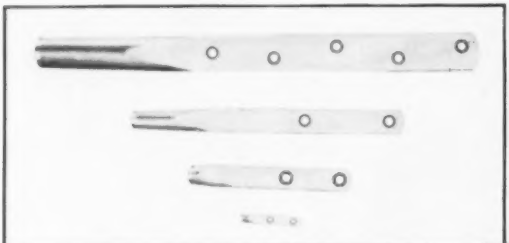
The Coaptation plates are used to impact the fracture ends forcefully and hold them firmly impacted. Such impacted coaptation facilitates uninterrupted blood supply to the traumatized bone cells and promotes early bone healing without excessive callus formation.

The Coaptor is a necessary tool in the application of these plates. Plates are available in seven lengths of 2½ to 6 inches.



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These acute-angled blade-plates are useful for fractures about the knee, especially supra-condylar fractures, "T" fractures, tibial plateau fractures and distal spiral fractures of the femur. The blade section is driven into the condylar area and the plate screwed to the femur or tibia for a simple, effective fixation.

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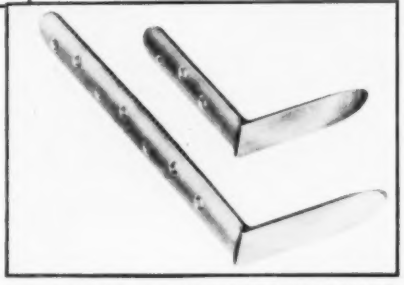

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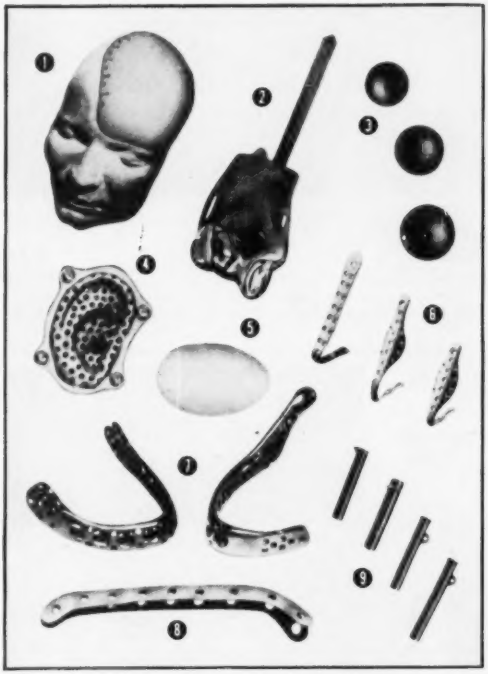

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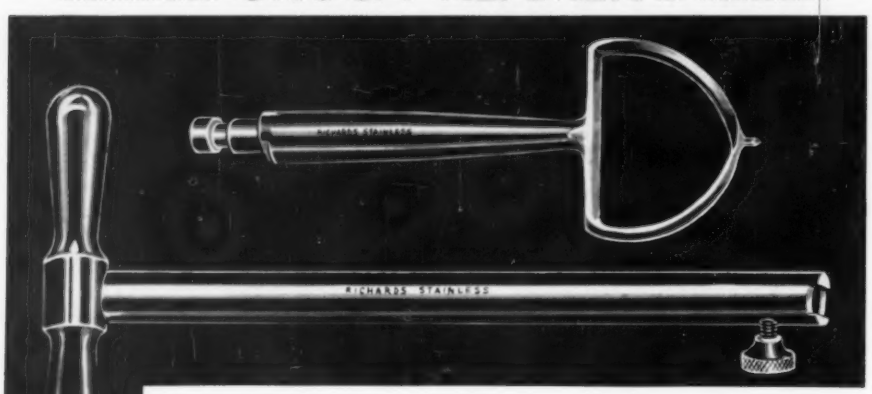

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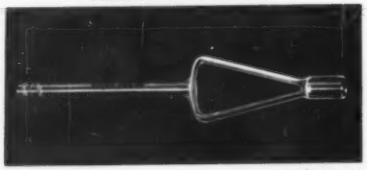

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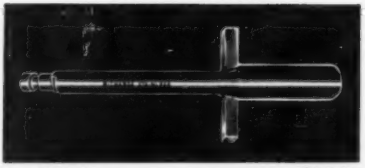

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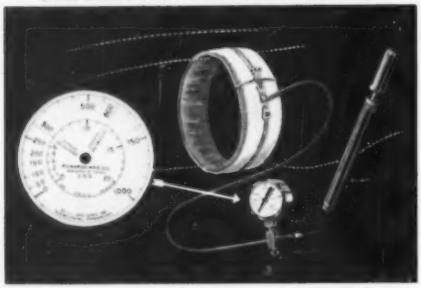

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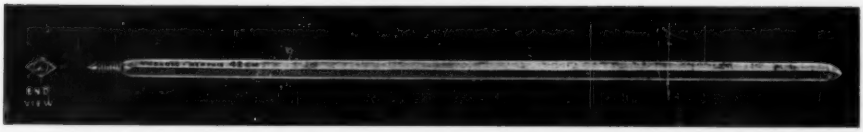

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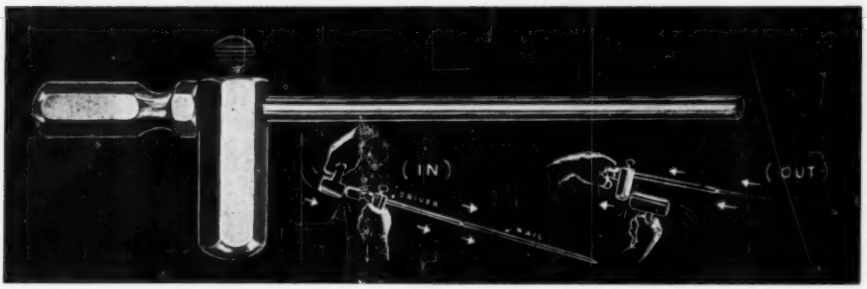

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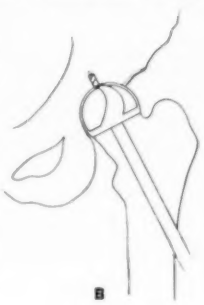
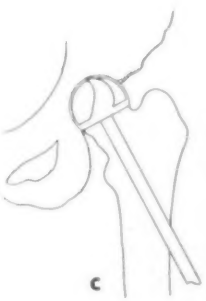
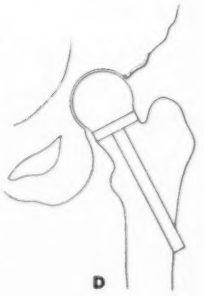




C. After socket reamer is well seated in newly formed socket, the drill-tipped shank is removed and the blunt-end shank inserted. The reaming is now completed, easily, safely, and smoothly.

D. Final restitution of joint. Note how strong existing acetabulum is utilized to form a supporting shelf. Roger Anderson Femoral Head fits perfectly and concentric articulation has been achieved in even this problem situation.



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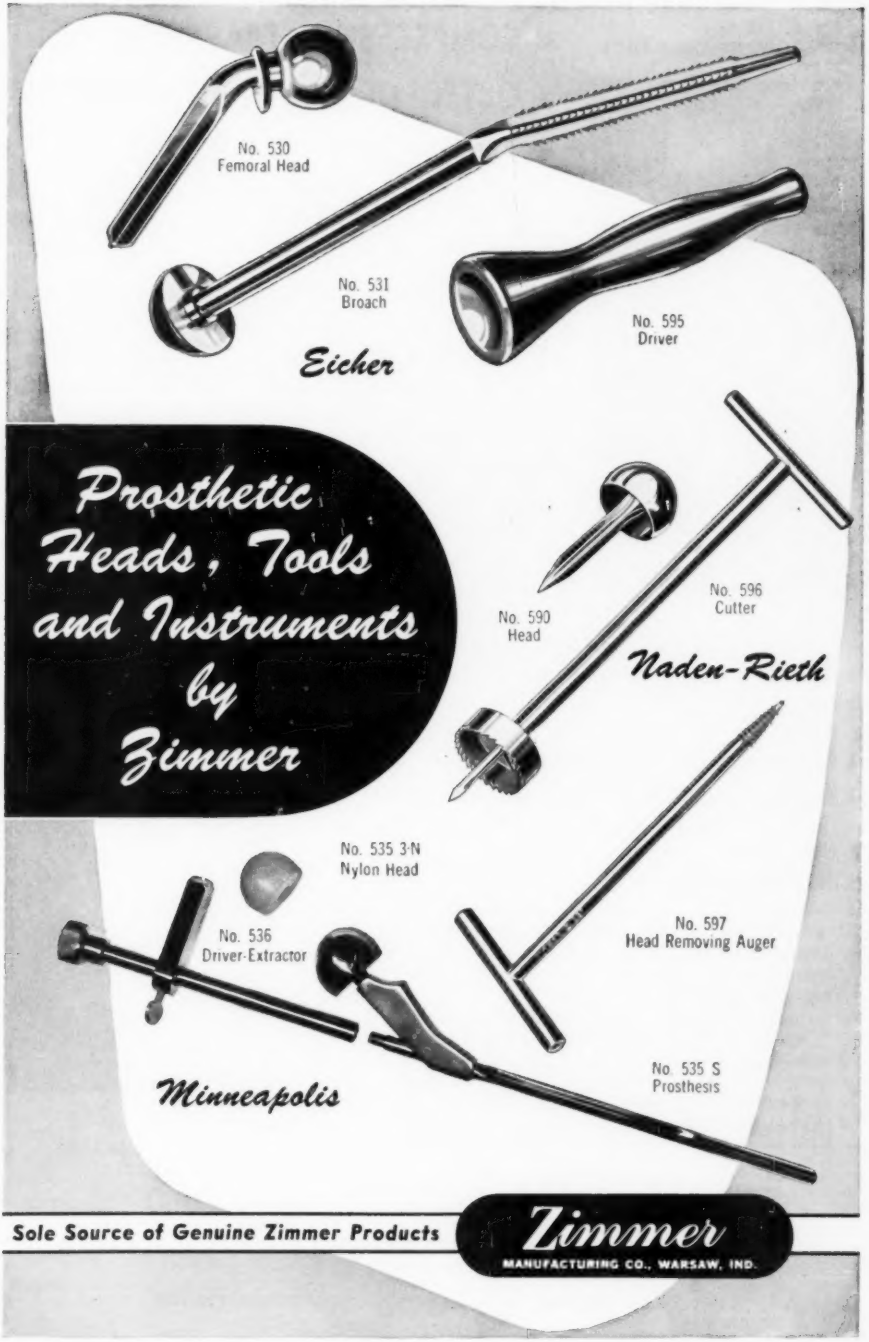
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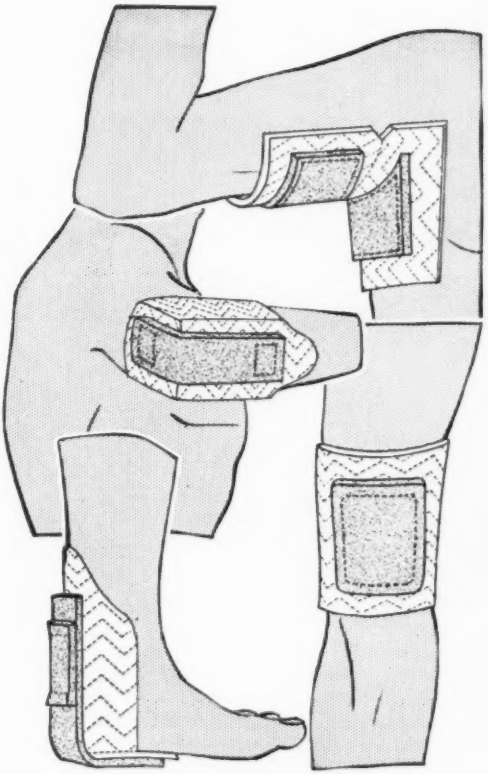

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RIGHT

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LEFT

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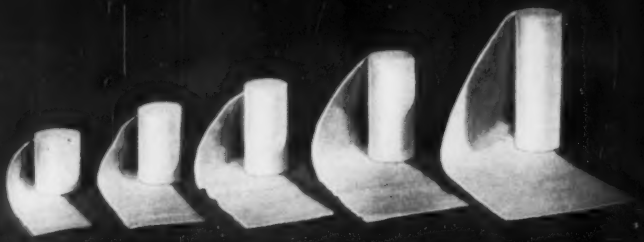

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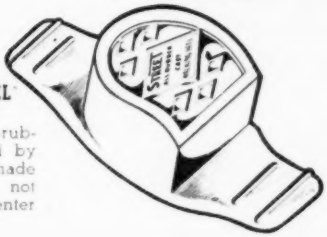

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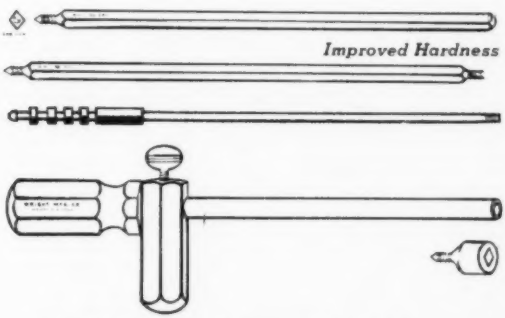

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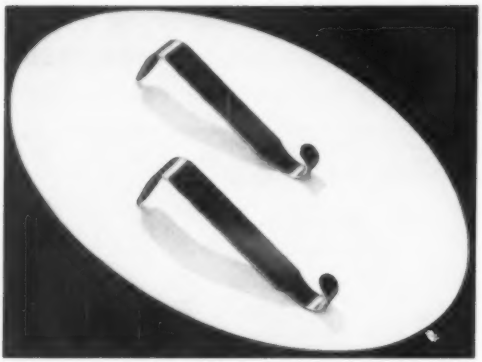

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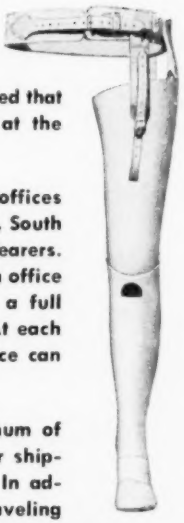

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The Journal of Bone and Joint Surgery

American Volume

Orthopaedic Surgery In Latin American Countries

An Editorial

In this issue of *The Journal* (pages 506–553) there appears a group of articles by eminent Latin American surgeons in which they recount the story of the development and advancement of orthopaedic surgery in their countries during the last half century. Interest in their orthopaedic background has long been keen, because of the many brilliant contributions of Latin American surgeons to surgical progress, and these articles meet a long-felt need. The reports have been made possible in large measure through the scholarly researches of the authors, often in collaboration with our Latin American Corresponding Editors.

As in most countries, the development of orthopaedic surgery as a division of general surgery has come through recognition of the need of special care of certain conditions, now recognized as orthopaedic, in children; the early chapters of the history of orthopaedics were written on the wards of children's hospitals. The care of adults afflicted with orthopaedic conditions was formerly part of the work of "general surgeons". The fundamental similarity of these conditions in the two age groups, of their underlying principles, and of the techniques of treatment in each became apparent as time went on. Then, too, orthopaedic surgery developed with amazing rapidity; more exacting techniques and the requirements of a broader knowledge made specialization inevitable. Gradually the care of orthopaedic conditions in children and adults has become the responsibility of surgeons especially trained in this field. More recently the vast field of the care of accidental injury has been added to the work of the orthopaedist.

Because surgeons from the Latin American countries early recognized the importance of personal observation of the work in similar fields in clinics throughout the world, the development of the specialty in their countries shows the influence of the European schools of surgery to which they went for study. Some of the services in their hospitals have been set up according to the patterns of orthopaedic and traumatic services in Germany, in Italy, in France, or in the United States, according to the country in which the first chiefs of staff had their introduction to orthopaedic surgery. The *Istituto Rizzoli* in Bologna has had a wide influence on the development of orthopaedic surgery in several of the South American countries, because leading surgeons in this field had the privilege of studying under such masters as Codivilla and Putti. Various other institutions in Italy, Germany, and France have influenced the development of work in other centers. In the last twelve or fifteen years the hospitals in the United States have been more accessible to these surgeons than have the European clinics.

All who have followed the literature of the Latin American countries have learned how much brilliant original work has been done in their clinics. It is hoped that in the years to come, many surgeons will wish to visit these countries and to see for themselves the outstanding work which is being carried on there. Each group has much to gain from the give-and-take in ideas which inevitably flows from a free interchange of visits.

Certainly the story of fifty years of orthopaedic surgery in some of the Latin American countries should afford a deeper understanding and greater appreciation of the superb work of the pioneers, as well as of the outstanding achievements of present-day surgeons in these countries.

ORTHOPAEDICS IN MEXICO

BY JUAN FARILL, M.D., MEXICO, D.F., MEXICO
Chief Surgeon of the Mexico Unit of the Shriners' Hospital for Crippled Children

To prepare and write an article on the advance of orthopaedics in Mexico during the last fifty years is a great task, because behind modern Mexico are hidden the folklore of the Aztec world and the events of the Colonial Period, unknown to most persons. These, in my opinion, should be better known, not only for arousing the enthusiasm of those who love to search in the treasures of old manuscripts, ruins, and traditions, but also for preserving the interest in the background of our specialty in the Americas.

Recent improvements in treatment of diseases of the locomotor system, be it operative or otherwise, have advanced the functional rehabilitation of the body. These have been made possible through the devising of practical methods of treatment as a result of research and clinical study carried on in the more advanced countries, where adequate surgical facilities are available. In other countries the history of modern orthopaedics is summed up primarily in the adoption of standard methods and, to a lesser extent, in their modification through research available in their environment.

It happens that in Mexico an exception can possibly be made, because, before the Spanish conquest, the Indians had developed a high plane of culture for their times, which should be explored more deeply and which should be better known. Has Mexico contributed to the medical culture of the world by initiating and introducing techniques related to orthopaedics? While further research work must be carried on, there is no doubt that some facts are worth knowing, even though they be only in a narrative and given in chronological order, because of the limitation of space.

Medicine maintained a high level among the Aztecs, in some ways superior to that among the Europeans of that time. Hernando Cortes recognized it when he refused to ask for Spanish doctors, declaring that the Mexican doctors were good enough to take care of his troops, and even he was successfully attended by an Indian. The Spaniards found that the Aztec kingdom had botanical gardens where were cultivated medicinal herbs exclusively which the emperor distributed among those who practised the medical art. Similar gardens were established later in some parts of Europe. The observation of the sick led doctors to describe different forms of paralysis according to its distribution, as well as rheumatism, gout, congenital defects, wounds, and infections of different organs.

They had "specialists" in internal medicine (*tlama-tepatiticitl*), in surgery (*toxoxotlaticitl*), in dentistry (*tlancopinaliztli*) who used to make wonderful ornamental jade inlays, and in bone-setting (*teomiquetzani* or *tepatitliztli*). The latter possessed "great ability in treating wounds, dislocations, fractures, and tumors".

Sutures of the wounds of the nose and of the mouth were done with long hairs and, when the wounds were close to the lips, liquid latex (*ulli*) was applied over them. When the nose was absent, a new artificial one, made of "something else", was applied.

In the practice of medicine these early doctors were guided by experience, superstition, and religion.

The Aztecs used traction, countertraction, manipulation, and immobilization for treating fractures and dislocations. Herbs were applied to hasten union and to treat infections, oedema, and pain. For the treatment of oedema around the fracture, they usually resorted to punctures. In fractures which did not unite, they scraped the bone and "put into the medullary canal a stick of very resinous wood of the kind used as candlewood in order to set the bone firmly, closing the wound". This quotation from Sahagún shows us that intramedullary fixation was practised by the Aztecs of that time.

The external immobilization of fractures, after reduction had been accomplished,

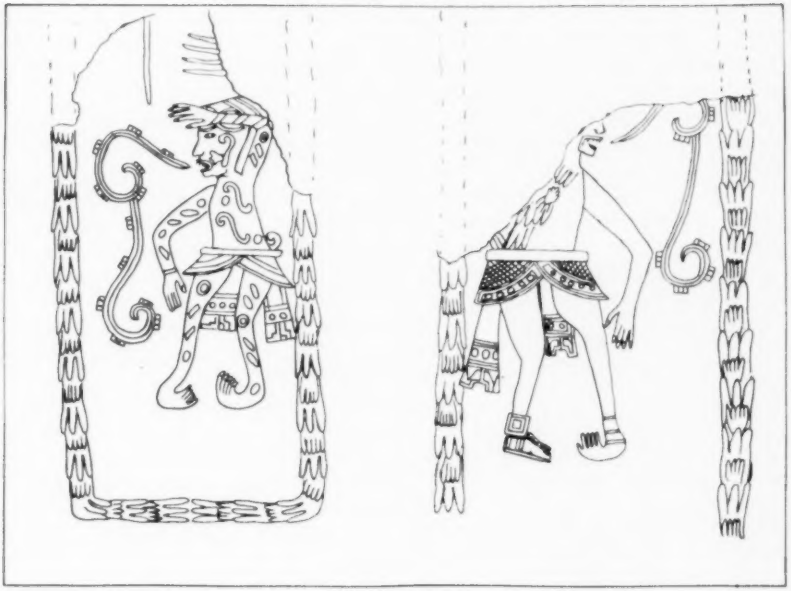

FIG. 1

Drawings from the frescoes of recent excavations at Teotihuacán, Mexico, which show (at the left) a boy with bilateral club-foot and (at the right) a case of unilateral club-foot deformity in an older person. In this latter case, the left hand near the knee suggests the possibility of paralysis. (Drawings are reproduced through the courtesy of Miss Eulalia Guzmán.)

was maintained by means of special wooden splints or by agave leaves fixed with leather straps or with an adherent resinous paste.

The Aztecs knew recent and old fractures and dislocations and described sprains. Their rather primitive nomenclature included the regional area of these injuries.

The Indians paid special attention to congenital deformities and believed that their god *Xolotl* produced monstrosities and deformities. In recent excavations near Teotihuacán, there has been unearthed what seems to have been some sort of infantile clinic. Miss Eulalia Guzmán, historian, has kindly allowed me to use a drawing from the frescoes of that place (Fig. 1) which shows cases of bilateral and unilateral club-foot deformity. The study of those ruins and new discoveries should add many more important facts.

Anaesthesia was used to alleviate pain, for pleasure, and to celebrate religious rites. The aforementioned historian, Miss E. Guzmán, as well as Diego Rivera, who is very well versed in Aztec archeology and history, informed me that human sacrifices were done with the victim anaesthetized and inebriated by the use of some plants and that, if he felt pain during the sacrifice, the rites were stopped, if possible, for it was considered a disgrace to make him suffer.

The Aztecs used corn dough, previously boiled in lime water, set outdoors to sour and ferment until of a yellowish-red color (penicillin?), as a base for a cool drink or as a poultice for infected wounds. This is still a practice in some parts of Mexico.

Soon after the Spanish conquerors came to Mexico, Cortes established the *Hospital de la Limpia Concepción de Nuestra Señora*, later named *Hospital de Jesús Nazareno*. This hospital, established in 1524, was the first hospital founded on the American Continent.

In 1536, bishops Zumárraga and Fuenleal dedicated the *Colegio de Santa Cruz de Tlaltelolco* to the Indians; in this college medicine was taught for the first time in the Americas.

In 1553, the *Universidad de Mexico* was inaugurated, and in 1576 the first necropsies and anatomopathological studies were performed on the occasion of a typhus epidemic.

In 1585, the *Tribunal del Protomedicato* was initiated, and later a bone setter was added to its staff which shows the importance attached to traumatology.

In 1645, the University Constitution adopted a law making it compulsory for the students to practise human dissections or to attend them; without this experience the students were considered disqualified for their studies.

In 1580, V. Gregorio López wrote the first book on therapeutics in America, published in 1672, in which he described the oral use of mandrake as a method for producing unconsciousness and senselessness during a period of three hours, recommending it during the cutting or cauterizing of a bone or a limb.

Fig. 2
Dr. Aureliano Urrutia

In 1845, Dr. Matías Béistegui and Dr. Francisco Vértiz successfully performed a blood transfusion following Blundell's method. According to Herrera, this was probably the first transfusion in the Americas.

In 1847, Dr. P. Martínez del Río used ether anaesthesia for the first time in Mexico.

In 1869, Dr. José M. Barceló performed a shoulder resection for the first time in Latin America. Conservative surgery was initiated in Mexico at that moment.

In 1875, Dr. Silvino Riquelme wrote on the advantages of ischaemia in surgery, and in 1880 Dr. José M. Gama described his method for shoulder disarticulation, avoiding damage to the posterior circumflex artery.

In 1881, one of the most brilliant Mexican surgeons, Dr. F. Montes de Oca, described his method for amputating the leg, which method is still in use to the great satisfaction of people who are unable to wear a prosthesis.

In 1896, Dr. Tobias Nuñez, in the Juárez Hospital, took the first x-ray picture, in a case of trauma to the right elbow.

The influence of the French school of medicine was absolute in Mexico, as well as in other Latin American countries from the last part of the nineteenth century until the end of the First World War, when the American school gradually came to predominate. One of the best examples of this is the fact that the French school seldom recommended surgery in the very young with tuberculosis of bones and joints, limiting resections and amputations to adults. This conduct was changed after the Albee and Hibbs methods of joint fusion became established. In Mexico, Lavista (1900) and Urrutia (1903) practised synovectomy for treating tuberculous synovitis. Failure led to discarding the routine surgical treatment in this disease and, although possibly in previous years certain surgeons had performed arthrodesis in some cases, the routine treatment by arthrodesis in bone and joint tuberculosis in Mexico was initiated in the *Hospital General* by Farill in 1934.

Aureliano Urrutia used astragalectomy as early as 1897 for correcting club-foot and for treating purulent arthritis of the ankle.

In 1911, Adrián de Garay applied tendon grafts for the section within the hand.

In 1914, Dr. G. Díaz Lombardo was one of the most enthusiastic surgeons in orthopaedics, helping many of his students to perform operations in this field. Dr. Rojas Loa and Dr. J. Castro Villagrana, among others, became prominent in this kind of surgery.

Dr. Castro at that time used internal fixation with metal plates, and later on applied bone grafts in ununited fractures and in cases of Pott's disease. He directed Dr. M.

Meneses' research work on bone grafts in dogs.

In 1920, Dr. Manuel F. Madrazo, after post-graduate training with Dr. Finkelstein in New York, brought into Mexico the first Albee electric saw and two orthopaedic tables. He performed in that year the first spine fusion in Mexico and was the first physician who devoted his practice exclusively to orthopaedic surgery. For all practical reasons, that period initiated the practice of modern methods in bone and joint surgery in Mexico, arousing the interest of many young doctors who wrote theses on these subjects.

In 1922, Dr. A. Ortiz Tirado was appointed Head of a Surgical Service in the *Hospital General;* he transformed this service to a service of bone and joint diseases.

Dr. Julián Villarreal, in 1924 and 1925, presented before the *Academia Nacional de Medicina* his results of research done on "turkey and goat bone grafts".

In 1928, Dr. Darío Fernández successfully performed a lateral cordotomy in a case of intractable pain, and in 1937 the same great surgeon described his technique for the interinnomino-pubic disarticulation.

In 1932, Dr. Ulises Valdés started the treatment of osteomyelitis by maggots in Mexico, and in the same year Dr. G. Gómez Azcaráte initiated the Orr treatment in the Juárez Hospital.

In 1933, Farill succeeded Ortiz Tirado and was appointed head of the Orthopaedic Department at the *Hospital General* where, with the close collaboration of Dr. Eduardo Gómez Jáuregui, he put into practice, probably for the first time in Mexico, skeletal traction and fixation, extra-articular nailing of the neck of the femur under x-ray control in two planes, myelography for diagnosing protrusion of the intervertebral disc, arteriography for differential diagnosis between tumors and inflammatory conditions of bones, systematic early plaster-cast treatment of congenital club-foot in infants, systematic surgical treatment of tuberculous osteo-arthritis, epiphysiodesis for arresting growth, shelf operation and subtrochanteric osteotomies for hip dislocation, fascial abdominal transplants according to the Lowman technique, and substitution of a fibular graft from the sound leg for the destroyed shaft of the tibia.

In 1935, after two years of work toward the rehabilitation of the crippled, the Mexican Society *Amigos del Niño Lisiado* was founded. Its first President was Dr. Juan Farill, who in 1942 became Executive President of the International Society for the Welfare of the Crippled, holding office until 1948. This campaign conveyed to the public the need for having orthopaedic services within the hospitals and fired more young doctors with enthusiasm to become orthopaedic surgeons.

In 1937, Dr. Alfonso Ortiz Tirado, aided by funds derived from his magnificent voice, built a large clinic of traumatology and orthopaedics.

In March 1937, the first and only issue of the journal *Revista de Ortopedia y Traumatologia Esquelética* appeared, published by Farill. This journal, supported by his private funds, could not continue in publication for lack of financial aid.

In 1943 the *Hospital Infantil*, one of the best in the world, was established. Its third floor was devoted to surgery with two orthopaedic services, headed by Farill and Velasco Zimbrón.

In March 1945, the International Association of Shriners established its first Latin American unit. Farill was appointed Chief Surgeon, with the assistance of Velasco Polo and Orellana. In it, interesting work has been performed, such as arthrography and treatment of congenital dislocations of the hip, tendon transplant of the tibialis anterior to the insertion of the peroneus brevis in paralytic club feet, 324 open reductions of fractures of which 217 have been intramedullarly fixed without accident or non-union, and x-ray research work on dislocated hips and on bone measuring. Other young doctors have been trained in this Unit. This token of international friendship has served as magnificent proof of true good-neighbor policy. In 1945 the Shriners established a convalescent home with fifteen beds.

In March 1945, Dr. E. Gómez Jáuregui was appointed head of the Orthopaedic Department at the Children's Hospital, succeeding Farill; there he has performed more than 100 of Brittain's arthrodesis of the hip using the Trumble approach, biopsy of the iliac lymph nodes, and interesting research work.

In April 1944, Dr. J. Carmona Paul n, Dr. José Zapata, Dr. Ladislao Solares, and Dr. E. Miranda Ortiz founded the *Sociedad Mexicana de Ortopedia*, which includes the majority of the orthopaedists in Mexico City. This Society held its first meeting, in connection with the National Assembly of Surgeons, in November 1950. *Anales de Ortopedia y Traumatología* is the name of the journal which has been published by this Society since 1950. The works of its members appear in this publication.

In 1944 the *Instituto Mexicano del Seguro Social* founded the *Hospital de Ortopedia y Traumatología*, the director of which is Dr. Jose de Jesus Dominguez. This Hospital has 200 beds and cares for about 250 out-patients daily. It is very well equipped; it has surgical, physiotherapy, reeducational, x-ray, and out-patient departments. An adequate medical staff cooperates with its Director. Statistics show that more than 250 cases of recurrent dislocation of the shoulder have been treated surgically here; Dr. Domínguez devised a perforator for the glenoid rim.

Mycosis of bones has been studied by Dr. Alejandro Castanedo, who reported his work in 1940, and by Dr. X. Romo Díez, who reported his findings in 1944 and 1950.

In 1944, Dr. Max Luft published one of the most comprehensive papers on primary osteomyelitis of the os calcis (thirty-two cases).

In 1948, the International Society for the Welfare of Cripples held its First Pan-American Meeting in Mexico, under the presidency of Farill. Soon afterward the charter meeting of the *Sociedad Latino-Americana de Ortopedia y Traumatología* was held at Acapulco with delegates from eight countries; Farill was elected President. The First Congress of the *Sociedad* was held at Montevideo and Buenos Aires in 1950, with an attendance of nearly 300 Latin American specialists. José Luis Bado succeeded Farill as President.

In 1948, Dr. A. Velasco Zimbrón published the preliminary report on the cadaver-bone bank established by him in collaboration with Dr. A. Chardy and Dr. L. Sierra Rojas.

In 1950, Dr. Carlos A. Orellana took a course in hand surgery with Dr. Sterling Bunnell.

Carlos Finck and J. Vargas Sahagun are leading orthopaedic surgeons in Torreon; J. L. Salinas Rivero, Federico Muguerza, Everardo Lozano, and Rodolfo Rangel in the state of Nuevo Leon; Carlos Heredia, E. Escalante Alfaro, and Fernando Guzmán in Yucatán; Uribe Casillas, G. Santacruz, Salvador Garc'a, and V. Cambre in Jalisco; Diego Hinojosa in Tampico; Mauro Loyo in Veracruz; and Enrique Sotelo in Sonora.

The Mexican orthopaedists have been conducting research on different ailments and on techniques of the specialty and have published papers in several Mexican medical journals such as *Medicina*, *Revista del Hospital General*, *Revista del Hospital Infantil*, *Prensa Médica Mexicana*, and *Revista del Hospital Juárez*.

The teaching of orthopaedics has been conducted in the medical schools following the French plan, being included in classes on surgical pathology, surgical technique on cadavera, dogs, and human beings; and in the surgical clinics in the hospitals.

In 1943, Dr. Castro Villagrana gave the first course on bone and joint surgery in the Juárez Hospital. Farill started the yearly courses in orthopaedics in the *Hospital General* in 1939, and in 1944 he established the Orthopaedic Department of the *Facultad de Medicina* and was appointed its Professor; in 1946 his class was transferred to the postgraduate school. Orthopaedics is taught as a special class in the *Facultad de Medicina* of Yucatán, which was established in 1944, the same year as the Orthopaedic Service of the *Hospital O'Horan*. Dr. Escalante Alfaro has been Professor and Head of the Service since that time. In Monterrey, Dr. J. L. Salinas Rivero is Professor of Orthopaedics in the *Facultad de*

Medicina. Services of the specialty have been introduced in the Muguerza and General City Hospitals.

Dr. Aureliano Urrutia, the gifted Mexican general surgeon who in 1897 was the first in Mexico to use astragalectomy for the correction of club-foot deformity, tried synovectomy of the knee in a case of tuberculosis in 1903, used arthroplasty of the elbow widely, and performed numerous operations for bone and joint ailments. He was Professor *par concours* of Surgery in the *Facultad de Medicina de Mexico* in 1912 and later was Dean of the *Facultad* and Director of the *Hospital General*. His talent and activity allowed him to improve the teaching of medicine in Mexico.

Dr. José Castro Villagrana, Professor of Surgical Therapeutics since 1926 at the *Facultad de Medicina*, of which he is Dean at the present time, is President of the Mexican Committee of the American College of Surgeons and of the International Society of Orthopaedic and Traumatic Surgery; he is a member of numerous medical societies. He has been one of the pioneers of modern bone surgery in Mexico. He has written papers on resections of the lower jaw, melorrheostosis, tumors of bone, dislocations of the patella, compound fractures, scoliosis, and arthrodesis of the tuberculous hip.

Dr. Manuel F. Madrazo was the first physician who had opportunity for postgraduate study in New York and in several European hospitals. He practised orthopaedics exclusively for some years after 1920. Also in 1920 he performed the first spine fusion in a case of Pott's disease. His ability and devotion brought to him great respect and consideration.

Dr. Alfonso Ortiz Tirado, well known surgeon who established the Service of Bone and Joint Surgery at the *Hospital General* in 1922, provided modern equipment for it with the funds derived from his singing. In 1937 he established a private orthopaedic hospital which now belongs to the *Instituto del Seguro Social*. He has enjoyed a large orthopaedic practice and has become internationally known in this field through numerous operations which he has performed.

Dr. Eduardo Gómez Jáuregui is at present Head of the Orthopaedic Departments at the *Hospital General* and at the *Hospital Infantil*. He has performed a large number of arthrodeses of the hip after the method of Brittain, in some of them using the Trumble approach, as well as many other operative procedures.

Dr. A. Velasco Zimbrón established the first bank of bone from cadavera. He has devised several operative techniques such as those for spine fusion and surgical treatment of prognatism. He established and directs the Hospital of Guadalupe and the convalescent homes for crippled children, *German Díaz Lombardo*, *Juan María Rodríguez*, *Consolación*, *Primavera*, and the one supported by the Lions Club.

To Dr. Arthur Steindler who is the professor under whose supervision the largest group of Mexican orthopaedists have been trained; to Dr. Caldwell, Dr. Bunnell, Dr. Chandler, Dr. J. E. M. Thomson, Dr. Oscar Lee Miller, Dr. Samuel Kleinberg, Dr. Alfred E. Gallant, and to several other specialists in the United States, and to Dr. Luis Iglesias, Dr. J. I. Tarafa, and Dr. A. Inclán of Cuba, who have trained Mexican doctors on their services or who have come to Mexico to lecture, the Mexican orthopaedic surgeons express their gratitude. They are also indebted to the former Mexican physicians who have aroused their interest and helped them in obtaining their training and experience.

The author comprehends the limitations of this modest effort, but he hopes that some capable men will undertake the important historical research to further the study and to clarify the details pertaining to Aztec medicine. The books from which the foregoing information was taken are the most faithful and reliable. Special mention must be made of

the book of Sahagún, *Historia de las Cosas de Nueva España*, written in the sixteenth century, and edited from the old Florentine manuscript, which is considered the best in describing the life and costumes of the Aztecs.

The author's appreciation is extended to Miss Eulalia Guzmán for her kindness in allowing the reproduction of the drawing from the frescoes of Teotihuacán and to Mr. Diego Rivera for his important contribution. Acknowledgment of the valuable data on the advance of modern orthopaedics is given to the doctors mentioned in the bibliography for their personal communications and especially to Dr. Carlos A. Orellana for his revision of the English manuscript.

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FIFTY YEARS OF PROGRESS IN ORTHOPAEDICS AND TRAUMATOLOGY IN BRAZIL

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The first reference to orthopaedics which we were able to find in the Brazilian medical literature dates back to the time of the Brazilian Empire. It was a petition from a Rio de Janeiro surgeon, Antonio José Peixoto, to the Emperor, asking permission and help to build an orthopaedic institute. Imperador Pedro II referred the petition to the *Academia Imperial de Medicina* which was his practice in medical matters. Transcribed in the *Anais da Academia Nacional de Medicina* (Vol. 10, pages 189–203) is the answer given by Nunes Garcia who was then the well known Professor of Anatomy of the *Faculdade de Medicina do Rio de Janeiro*. He thought orthopaedics should be made a part of the medical school itself so that, as he expressed it, gymnastics could be taught in the *Collegio Pedro II* and orthopaedics could be taught in the *Clinica da Faculdade de Medicina*, provided that the necessary equipment were made available.

This document demonstrates that as early as 1841 the *Faculdade de Medicina* was already asking the government for facilities to teach orthopaedics. It seems incredible that not until seventy years later, in 1911, was Nunes Garcia's request granted, when the teaching of the specialty was established officially in Rio de Janeiro.

It was not until late in the nineteenth century that Brazilian orthopaedics actually began to develop. Prior to this, orthopaedic cases were referred to general surgeons or pediatricians, some of whom gained a considerable reputation in this, their chosen field. Thus, at that time, Barão Afonso de Carvalho performed osteoclases, osteotomies, and other orthopaedic operations, and Pertence was known as an expert traumatologist.

In 1888, during the time of the Emperors, the Minister of Education, Visconde de Saboya, established the Chair of Pediatric Surgery, which was held by Candido Barata Ribeiro (Fig. 1). He was a brilliant and talented surgeon who devoted himself to orthopaedics with the same enthusiasm that he showed in his political life, as the first Mayor of the City of Rio de Janeiro, as Senator, and even as Justice of the Supreme Court. He was particularly interested in the treatment of club feet and bone and joint tuberculosis. Some of his writings are remarkably advanced for his time. In 1898 he wrote a book on the forcible correction of kyphosis.[18] Less skillful surgeons caused this method to be abandoned on account of complications arising in cases of Pott's disease. His method, however, had the merit of emphasizing the importance and the possibilities of progressive correction of deformity, one of the basic concepts of orthopaedic treatment.

Ovidio Meira was Barata Ribeiro's pupil and in due time became an outstanding orthopaedist.

At approximately the same time, there was in Rio de Janeiro another distinguished orthopaedist, Joaquim Pinto Portelia (Fig. 2). In 1888 after travel and study in Europe he wrote *Impressões de uma viagem à Italia e França debaixo do ponto de vista da Moderna Ortopedia*, in which he sought to "*chamar a atenção dos médicos brasileiros sôbre essa nóva especialidade afim de que a ela alguns se dedicassem seriamente e completamente como os ortopedistas europeus e americanos*" (draw the attention of the Brazilian physicians to this new specialty, so that some of them would earnestly and thoroughly dedicate themselves to it, as have European and American orthopaedists). In that paper Portella also described the methods of treatment most common in the countries he visited. A detailed description of the treatment used in Italy for the correction of rachitic deformities was given.

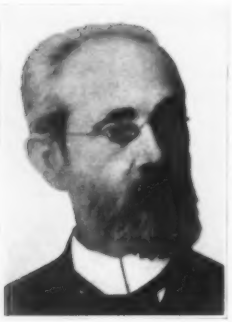

FIG. 1
Candido Barata Ribeiro
1843–1910

FIG. 2
Joaquim Pinto Portella
1860–1934

FIG. 3
Barboza Vianna
1890–1946

In the same year (1888) he wrote *Necessidade da fundação de institutos ortopédicos e hospitaes marítimos no Rio de Janeiro*, an article in which he outlined his brilliant plan for the development of orthopaedics in this city. It was not long before his ideas bore fruit with the foundation of an orthopaedic hospital. We are indebted to Portella for the creation of the first two orthopaedic services in Brazil. The first was founded in 1911. It was a department of the *Santa Casa* (a charity hospital) and was well suited to teaching. The second one, the *Hospital São Zacharias*, established in 1914, was also well equipped and had 150 beds for children under the age of fourteen, a good operating room, and a plaster room.

In 1911 the Chair of Children's and Orthopaedic Surgery was established in the *Universidade do Rio de Janeiro*. Attendance at the course in orthopaedics was compulsory and at the end of the course the students were examined. The distinguished surgeon, Nascimento Gurgel (1876–1928) was appointed professor. With his great knowledge and remarkable skill as a teacher, he achieved great renown throughout Latin America. He has left many publications of note on such subjects as poliomyelitis, deficiency diseases, and the encephalopathies. He retired in 1925, leaving many disciples, some of whom have become famous orthopaedic surgeons.

At this stage of its development, Brazilian orthopaedics was dominated by the European influence, particularly the French. This is apparent, for instance, in the teaching institutions which were organized like those in France, where there was no place for the care of adults with orthopaedic conditions. The orthopaedic departments of the Brazilian general hospitals were only intended for children and adolescents. Many years were to pass before traumatology and orthopaedics were to be associated in Brazil without regard to the age of the patient. The first step toward this goal was taken in 1911, at the *Universidade do Rio de Janeiro* when the Chair of *Pediatria Médica e Cirúrgica* was divided into two new chairs—*Clínica Pediátrica Médica* and the *Clínica Pediátrica Cirúrgica e Ortopédica*. Another milestone was reached in 1944, when the chair of *Clínica Cirúrgica Infantil e Ortopedia* of the *Universidade de São Paulo* was converted into the *Clínica Ortopédica e Traumatológica*. The hospital facilities of the Clinic were then set up to treat children and adults of both sexes.

PIONEERS

The year 1925 marks the beginning of a new era in the history of the development of orthopaedics in Brazil. The ground had been prepared; and now, by a strange coincidence, in the same year, the four most important Brazilian universities started a movement to revise the teaching of orthopaedics. In Rio, after Gurgel's retirement, Barbosa Vianna

became professor. In São Paulo, Rezende Puech (Fig. 4) was appointed to the newly created Chair of *Clínica Cirúrgica Infantil e Ortopédica*. In Recife (Pernambuco), Barros Lima and, in Bahia (Salvador), Durval T. da Gama were appointed to the newly created chairs of the same title.

FIG. 4
Rezende Puech
1884–1939

During the next fifteen years was done most of the pioneer work which laid the foundations of the present era. In that period orthopaedics was recognized in almost every Brazilian medical school; orthopaedic services were created in many hospitals, the *Sociedade Brasileira de Ortopedia e Traumatologia* was founded and two journals devoted to the specialty were organized: *Arquivos Brasileiros de Cirurgia e Ortopedia* and the *Revista Brasileira de Ortopedia e Traumatologia*.

Each university became an orthopaedic center, stimulating further development of the specialty. In Rio, Barbosa Vianna (Fig. 3), former professor of anatomy, organized the teaching of the specialty, using didactic methods to compensate for the lack of adequate hospital equipment. The small ward of the *Hospital São Francisco de Assis* was the only service available in 1927. It was far too small to permit the formation of an orthopaedic staff or the teaching of medical students. In spite of this, with his great determination, Barbosa Vianna was able to contribute a great deal and to establish the good reputation of orthopaedics in Rio. His enthusiasm and his ability as an organizer were most apparent in the Rio medical societies, where he occupied many leading positions. He was a founder of the *Colégio Brasileiro de Cirurgiões*. In 1935 he was especially invited to give a series of lectures at the University of Paris. They were published later in a book[17]. The chief subjects which he covered were: congenital scoliosis, Madelung's disease, amputation prostheses, and the treatment of club-foot. He presided over the Congress of the *Sociedade Brasileira de Ortopedia e Traumatologia* held in Rio in 1942.

At the *Universidade de São Paulo*, Rezende Puech (Fig. 4), an earnest teacher with a stimulating personality, became professor. He started his orthopaedic career as chief of the Orthopaedic Service at *Santa Casa*, where he demonstrated outstanding qualities as an organizer and his sincere dedication to his work. He was in a way a self-made orthopaedic specialist; he never had time for travel or for study abroad. He had a well deserved reputation as a clinician and, when the Chair of Pediatric Surgery and Orthopaedics (*Clínica Cirúrgica Infantil e Ortopédica*) was established at the University of São Paulo in 1925, he was elected to that position. He enjoyed considerable prestige and knew how to use it to advance the new specialty. He built an excellently equipped hospital, the *Pavilhão Fernandinho Simonsen* (Fig. 6), on the grounds of the *Santa Casa*, since that is a large and well organized charity hospital. Puech planned the organization and the teaching of orthopaedics in the *Pavilhão Fernandinho*, with its 150 beds, according to the most advanced ideas of his time. Due to special regulations of the hospital, however, these facilities were only available to children under the age of fifteen.

In 1935, as part of his vigorous program to advance the specialty in Brazil, Puech, in

association with Achilles de Araujo, Barros Lima, and a group of other enthusiastic orthopaedists, planned and founded the *Sociedade Brasileira de Ortopedia e Traumatologia*. Puech was its first president, in 1936. His multiple activities left him little time to write, but he still managed to produce such significant works as: *Doença de Heine-Medin*, *Contribuição ao estudo da coxa plana*, and *Problema da Luxação Congênita no Brasil*, a valuable monograph on the subject. He designed a method for the treatment of paralytic talipes calcaneus, the results of which were later published by his collaborators.[97] He was a member of the International Society of Orthopaedic and Traumatic Surgery, as well as of a great many European and other orthopaedic societies in the western hemisphere.

Puech was also renowned for his knowledge of hospital administration and, in the latter years of his life, his advice was sought on the planning of almost every new hospital in the state of *São Paulo*. The *Hospital das Clínicas* of the University of São Paulo, for instance, was in large part planned by him.

He died in 1939, at the age of fifty-five. In spite of his early death, he had already paved the way for the teaching of orthopaedic surgery at the University of São Paulo Medical School, and had built and organized the *Pavilhão Fernandinho*, the first South American Hospital devoted solely to orthopaedic surgery. He had also played a major role in the foundation of the *Sociedade Brasileira de Ortopedia e Traumatologia* and had done much to raise the prestige of orthopaedic surgery, which was just beginning to be recognized in Brazil during his time.

Puech left a number of disciples who have carried on the work he had begun and who have come to hold positions of prominence in Brazilian and South American orthopaedics. Among these are Domingos Define, his close collaborator, and Orlando Pinto de Souza, Renato Bomfim, and Itapema Alves, his disciples in the *Pavilhão Fernandinho*.

The *Universidade de Recife*, in the northeastern part of Brazil, appointed Barros Lima in 1925 to the newly established Chair of Orthopaedics. Through his great efforts, it became

FIG. 5

A group photographed in 1936 during the first meeting of the *Sociedade Brasileira de Ortopedia e Traumatologia*. First row, left to right: José Londres, Vittorio Putti, Rezende Puech, Elyseu Guilherme, Domingos Define, and Barros Lima. Second row, left to right: Amorim, Godoy Moreira, Achilles de Araujo, Weinberger, and Bomfim. Third row, left to right: Frascá Define, and Caio Amaral.

an important center of learning and did much toward making orthopaedics a well known and accepted specialty in a large area of the Brazilian territory. One of the leading figures of the *Sociedade Brasileira de Ortopedia e Traumatologia*, he was its president in 1938. He founded in Recife the first Brazilian hospital for the care of osteo-articular tuberculosis, the *Sanatorio Infantil para Tuberculose Cirúrgica*. He also founded the *Arquivos Brasileiros de Cirurgia e Ortopedia*, a review of the specialty, which he edited himself and in which he published most of his numerous writings. The more notable of his works include: *A propósito do tratamento das fraturas do antebraço nas creanças*, *Tracion com hilos en las fraturas de femur de los ninos* (translated into Spanish and French), *Epifisite deformante da tibia*, *Neurofibromatose cutanea e ossea*, *Gibosidade por tetano*, *A propósito da genese da luxação coxo-femural*, *Tratamento da paralisia obstetrica*, and a book, *Tratamentos cirúrgicos da tuberculose ossea*, published in 1931.

In the *Hospital Santo Amaro* and later on in the *Hospital Infantil*, he organized efficient services and there he gathered around him several associates who have become outstanding orthopaedic surgeons, among whom are Bruno Maia and Ruy Batista.

He was appointed by the government to direct the state assistance to hospitals and in this position he rendered important and beneficial services. Later he was made Dean of the *Faculdade de Medicina* of Recife. He is a member of the International Society of Orthopaedic and Traumatic Surgery, as well as of a number of other national and foreign scientific societies.

Barros Lima never abandoned general surgery. Five years ago, after having made invaluable contributions to the cause of orthopaedics, he resigned his position as Professor of Orthopaedics, and was appointed Professor of Surgery of the *Faculdade de Medicina* of Recife. Ruy Batista, one of his disciples, was called to take his place as Professor of Orthopaedics.

SOCIEDADE BRASILEIRA DE ORTOPEDIA E TRAUMATOLOGIA

In 1935 a group of orthopaedists, led by Puech, Achilles de Araujo, and Barros Lima, founded the *Sociedade Brasileira de Ortopedia e Traumatologia* in São Paulo. The society originally included twenty-two surgeons, among whom were: Godoy Moreira, Domingos Define, Orlando Pinto de Souza, Mario Jorge de Carvalho, Caio do Amaral, José Londres, Renato Bomfim, Bruno Maia, Correa do Lago, Milton Weinberger, Silvio Marques, José Lima Batalha, and Antonio Longo.

The *Sociedade Brasileira de Ortopedia e Traumatologia* was the first orthopaedic society to be founded in Latin America. Its chief objectives were: to organize Brazilian surgeons specializing in orthopaedics and to protect and assure the prestige of this branch of surgery; to further the advancement and encourage the study and practice of the specialty; and to aid in the solution of medicosocial problems connected with orthopaedic surgery.

In the eighteen years since its foundation, the *Sociedade Brasileira de Ortopedia e Traumatologia* has achieved much, having overcome the natural difficulties and the lack of effectiveness inherent in every new organization. The tremendous area of Brazil added considerably to the difficulties during the early steps of the Society's development. It was only through the great enthusiasm of the pioneer members that the *Sociedade Brasileira de Ortopedia e Traumatologia* survived and grew so that it now has 130 members, the maximum allowed by the by-laws.

On July 1, 1936, the Society held its first meeting in São Paulo under the presidency of Puech. This was the first orthopaedic meeting ever held in Latin America. Among the distinguished guests was Prof. Vittorio Putti who addressed the membership on *Cirurgia ortopédica na medicina contemporânea*, in which he stressed the point that it was the orthopaedist's proper function to treat all patients with fractures admitted to general

hospitals. This responsibility for fracture treatment has been generally recognized in almost every country, despite the opposition of a few surgeons.

Since its founding, the *Sociedade Brasileira de Ortopedia e Traumatologia* has held nine meetings, one every two years. Some of these have been attended by surgeons from all over the continent. Important subjects in the field of orthopaedics and traumatology are always chosen with particular reference to local needs and interests. Some of the papers which have been given are: *Luxação congênita coxo-femural*, *Sequelas da paralisia infantil*, *Fraturas do colo do fêmur*, *Fraturas do tornozelo*, *Dores lombares*, *Osteomielite*, *Fraturas da coluna vertebral*, *Paralisias obstetricas*, *Tratamento das pseudoartroses*, *Pé torto congênito*, *Tuberculose osteo-articular*, *Fraturas do cotovelo*, and *Fraturas da diafise femural*.

In order to stimulate study and research, the Society has instituted biennial prizes for the best national contributions to orthopaedics or traumatology. In addition to its central organization, the *Sociedade Brasileira de Ortopedia e Traumatologia* has regional sections in several Brazilian states. These state societies hold bimonthly meetings for the presentation of symposia or the free discussion of subjects of interest.

The enumeration of these activities gives some idea of the vitality of the *Sociedade Brasileira de Ortopedia e Traumatologia*. It has been a powerful force for the advancement of Brazilian orthopaedics and an invaluable medium for a better understanding among the specialists themselves.

PRESENT CONDITIONS

The development of Brazilian orthopaedic surgery has been closely associated with the growth of the centers of medical teaching.

Orthopaedics is now taught officially in ten Brazilian medical schools: Belém, Recife, Bahia (Salvador), Niteroi, Curitiba, Porto Alegre, the two in Rio de Janeiro, and the two in São Paulo; thus the most important centers in the north, middle, and south of Brazil are covered. *Clinica Cirúrgica Infantil e Ortopédica* is the name given to all the chairs except the one at the *Universidade de São Paulo* and that at the *Faculdade de Ciências Médicas do Rio de Janeiro*. In these two the name of the department with its hospital service is *Clinica Ortopédica e Traumatológica*, a more fitting title.

At the *Universidade de São Paulo* Godoy Moreira succeeded Rezende Puech. After completing his internship in general surgery in São Paulo, Godoy Moreira worked as an assistant to Biesalski at the *Oskar-Helene-Heim* in Berlin, and later as an assistant to Putti at the *Istituto Rizzoli* in Bologna. On his return to São Paulo in 1934, he founded the *Instituto Ortopédico e Clinica de Fraturas*, a forty-bed hospital, devoted exclusively to the specialty.

In 1940, when he became professor, he began teaching orthopaedics in a small fifteen-bed ward in the *Santa Casa*, while waiting for the new facilities of the *Hospital das Clinicas*, then being built. In 1942 he was made Clinical Director of this Hospital, a post which he held for three years. During that time he organized the 120-bed department of Orthopaedics and Traumatology of that Hospital. He also persuaded the government to use the facilities of this Hospital for the care of the emergency cases of the city of São Paulo. Thus the *Hospital das Clinicas* of the São Paulo Medical School received a vast and invaluable flow of teaching material for all of its various clinics. In the highly industrialized city of São Paulo, however, with its heavy traffic, the 120 beds of the *Clinica Ortopédica e Traumatológica*, the new name given this service in 1944, were soon inundated by the tide of accident patients. Overflowing of patients into the corridors became a common scene and a new and larger hospital was needed. A magnificent, up-to-date, 280-bed hospital has been built, thanks to the prestige and vision of the Director, Godoy Moreira. It will house the *Clinica Ortopédica e Traumatológica* and is one of the most modern and well equipped orthopaedic hospitals in the world (Fig. 7). It will certainly play an important role in the future development of Brazilian orthopaedics and traumatology.

In 1945 and 1946 Godoy Moreira was invited by the Department of State of the United States and the British Council to visit the chief orthopaedic centers of both countries. During this year he gained first-hand knowledge of the advancements in the specialty during World War II.

In January 1946, he founded the *Revista do Hospital das Clínicas* where most of the papers of the *Clínica Ortopédica e Traumatológica* are published.

Among Godoy Moreira's works, special mention must be made of his research on fractures of the neck of the femur [72,73,74,75], and his contributions to the technique of bone-grafting[68]. Another significant contribution is the trephine [39] used for biopsy of deep bone tumors. Among his publications are: *Principios fundamentais do tratamento da paralisia infantil; Indicações dos transplantes osseos em cirurgia ortopédica; Tratamento da pseudo-artrose do cólo do fémur pela ósteosíntese; Tratamento das fraturas e pseudoartroses do cólo do fémur pela associação dos enxêrtos osseos esponjosos e cortical; Enxêrto bicondiliano; Fixação da cabeça femural na ósteosíntese do cólo do fémur: Tecnica e aparelhagem; Sequelas da paralisia infantil; Contribucion al estudio del sindrome de Volkmann; Anca a scatto; La disostose cleido-cranica come malattia ereditaria;* and *Luxations habituelles de la rotule.* He is a member of the International Society of Orthopaedic and Traumatic Surgery and of a number of other American and European societies.

There is also in São Paulo another outstanding orthopaedic center, *Pavilhão Fernandinho*, previously mentioned. As head of the orthopaedic department, Puech was succeeded by Domingos Define. He had specialized in orthopaedics under Glaessner in Berlin, and with von Bayer in Heidelberg, and afterwards with Putti in Bologna. In São Paulo he became one of Prof. Puech's greatest collaborators in the *Pavilhão Fernandinho*, where for many years he was in charge of the regular course in orthopaedic surgery at the *Faculdade de Medicina*. When he later took over the direction of the *Pavilhão Fernandinho* he was well qualified to give it a sound orientation and to maintain its well deserved reputation as a teaching and working center.

When the new medical school, the *Escola Paulista de Medicina*, was created, Domingos Define was made Professor of Orthopaedics. He was one of the founders of the *Sociedade Brasileira de Ortopedia e Traumatologia* and in 1940 he was elected its president. He has many publications to his credit. Among them are his studies on: *Novo processo para estabilizar a articulação tibio-tarsica no pé paralítico; A preluxação do quadril; Nóvas aquisições no terreno do tratamento das osteomielites; Traumatismos obstétricos da região escapulo-humeral; Etiopatogenia da coxa-plana. Estudo experimental; Fratura do cólo do fémur; Considerações sobre alguns casos de lesão da fibrocartilagem do joelho; Novo modelo de mesa destinada ao tratamento das fraturas da coluna vertebral; Tratamento das pseudoartroses congênitas dos ossos da perna.*

In Rio de Janeiro, Achilles de Araujo succeeded Barbosa Vianna in 1948. Brazilian orthopaedics is greatly indebted to this associate of Pinto Portella and Nascimento Gurgel. Araujo started working with them in 1914, in the old *Hospital São Zacharias*. In 1919, with Ovidio Meira, also a member of the same hospital staff, he performed the first vertebral arthrodesis, using Albee's technique. In 1930, Achilles de Araujo founded the *Clínica Ortopédica do Hospital Evangélico* with a well equipped department of traumatology for both children and adults. He is the Professor of Orthopaedics and Traumatology of the *Faculdade de Ciências Médicas do Rio de Janeiro.*

The foundation of the *Sociedade Brasileira de Ortopedia e Traumatologia* is partly the result of his tireless efforts. He was its president in 1937. In 1939 he founded the *Revista Brasileira de Ortopedia e Traumatologia*, in which he published most of his numerous works. Special mention should be given to the following: *Tratamento cirurgico da ausencia congênita da tibia; Reconstituição articular autoplastica do cotovelo baloiçante; Quadro redutor para tratamento das fraturas do membro superior; Osteodistrofia fibrosa localizada;* and *Fratura isolada da espinha iliaca anterior e superior.*

Achilles de Araujo is a member of the International Society of Orthopaedic and Traumatic Surgery and of a number of other foreign societies.

In Rio de Janeiro there are two other schools in which orthopaedics and traumatology are taught. The chair of *Traumatologia da Escola Nacional de Educação Fisica* is occupied by Caio do Amaral, a former student of Putti and traumatologist to the Brazilian Expeditionary Force in Europe during World War II; the other is the chair of *Clínica Cirúrgica Infantil e Ortopédica da Faculdade de Ciências Médicas*, to which Dagmar Chaves has been appointed.

In the *Faculdade de Medicina da Universidade da Baia*, in the northeast section of Brazil, Benjamin Salles succeeded Durval Gama in 1950. He has a well equipped service in the local *Santa Casa* and has published several works of which should be mentioned the *Tratamento do pé varo equino congênito*, a complete monograph, including the most recent contributions to the subject. He has studied in great detail the anatomy of congenital talipes. Among his other papers are: *Considerações sôbre o síndrome de Volkmann; Tratamento conservador da tuberculose osteoarticular na criança; Tratamento das fraturas do cólo do fêmur pela osteossintese com o parafuso de Godoy Moreira;* and *Em torno das fraturas supracondilianas do umero na criança.*

In the southernmost section of Brazil, in the city of Porto Alegre, Nogueira Flores was the first Professor of Orthopaedics. Cesar Avila succeeded him in 1944 and, with the help of collaborators, is organizing a good center for the teaching and practice of orthopaedics and traumatology.

TEACHING HOSPITALS AND ORTHOPAEDIC SERVICES

Up to approximately thirty years ago, adult patients with orthopaedic conditions, as well as fractures, were treated on the general surgical wards or in the children's infirmaries. Little by little, however, the need for specialized equipment and trained personnel became so obvious that orthopaedic sections were created in the general hospitals.

With the growth of the specialty in Brazil, several hospitals, both government and private, were built solely for the care of orthopaedic and traumatological patients. São Paulo and Rio de Janeiro led the new trend. Today dozens of such services are scattered throughout the country as special departments of the general hospitals.

Two orthopaedic hospitals, both located in São Paulo, deserve special mention; they are *Clínica Ortopédica e Traumatológica* and the *Pavilhão Fernandinho Simonsen.*

Clínica Ortopédica e Traumatológica

Built under the supervision of Godoy Moreira, for the purpose its name implies, this hospital has a capacity of 280 beds for adults and children. It possesses special facilities for the treatment of accidents and fractures, an air-conditioned surgical floor, a bone bank, a complete physiotherapy and rehabilitation department, with hot and cold pools; a special department for the construction of orthopaedic appliances; a special department for the treatment of infantile paralysis; a department of pathological anatomy with a specimen museum; and an amphitheater with direct ceiling view to two of the operating rooms.

The Clinic is located in the Medical Center of the *Faculdade de Medicina da Universidade de São Paulo* (Fig. 8). This is the only Latin American medical school with a Class A rating from the American Medical Association. It has good laboratory facilities, especially in the anatomy department. The bone bank of the Clinic has been used extensively. About one hundred operations were performed last year in which refrigerated bone was used.

In the Clinic's emergency department an average of forty new accident cases are seen every day. The medical students spend six months here and have an excellent opportunity to become familiar with most traumatic conditions. During its six years of existence, 48,292 patients have been cared for in the Clinic. This volume of work offers an exceptional opportunity for the study and teaching of the specialty.

The Clinic has twenty-five surgical assistants, and surgeons are on duty twenty-four hours a day to care for the emergency cases.

Pavilhão Fernandinho Simonsen

This hospital was built under the supervision of Puech and was finished in 1931. A 150-bed hospital for patients under fifteen years of age, it is at the present time under the direction of Domingos Define. It has a surgical floor, x-ray department, an orthopaedic appliances shop, lecture and class rooms, modern equipment for orthopaedic and pediatric surgery, and a well equipped and very active out-patient department. A physiotherapy section is located near the out-patient department. Due to its affiliation with the *Santa Casa*, it may use the laboratory and other facilities of that hospital.

In Rio de Janeiro, the *Pavilhão de Ortopedia e Traumatologia*, a division of the *Hospital São Francisco de Assis*, carries on the teaching of orthopaedics to medical students of the *Faculdade de Medicina da Universidade do Rio de Janeiro*. Designed by Achilles de Araujo, the *Pavilhão* has a capacity of fifty beds for adults and children. It is very well equipped with a modern surgical suite, class rooms, x-ray and physiotherapy departments, a library, and an out-patient department. An emergency clinic is maintained in the out-patient department.

FIG. 6

Pavilhão Fernandinho, São Paulo

Besides the teaching hospitals, there are in Brazil a number of excellent hospitals and institutions devoted to orthopaedics and traumatological surgery. Some of them are well worth mentioning. In Rio de Janeiro there is the *Serviço de Ortopedia do Hospital Jesus*, under the competent direction of Pinheiro Campos. It has eighty beds for children and adults. Pinheiro Campos started his career as Mario Jorge's assistant, and later went to the United States where he studied with Albee. An earnest worker, he has, with the help of a large group of collaborators, succeeded in making his service at the *Hospital Jesus* an excellent and well known orthopaedic center. He has devoted much attention to the study of poliomyelitis and has acquired a good collection of scientific films dealing with the disease. He is the President-Elect of the *Sociedade Brasileira de Ortopedia e Traumatologia*.

Also in Rio de Janeiro are the following hospitals:

The *Hospital Central de Acidentados* is under the direction of Mario Jorge de Carvalho, a student of Delbet and Rouvillois. Since 1928 he has been active in the field of traumatology. Dedicating himself particularly to the problem of industrial accidents, he has trained some well known assistants, such as Walter Barboza. The hospital has 100 beds and is fully equipped for the treatment of fractures and accidents.

The *Hospital Barata Ribeiro* is a beautiful, modern, eighty-bed children's hospital, headed by Luthero Vargas, who supervised its building in every detail.

Pavilhão Dodsworth is a thirty-bed hospital, directed by Dagmar Chaves and devoted to the care of osteo-articular tuberculosis. There is also the *Clínica Cirúrgica Infantil e Ortopédica* with eighty beds under the direction of Almeida Rios and Haroldo Portella. Finally, as important services existing in Rio de Janeiro, we must mention the *Clínica*

Ortopédica e Traumatológica headed by Caio do Amaral, the *Clínica Ortopédica da Santa Casa* managed by Henrique de Góes, and the *Clínica Ortopédica do Ipase* under the direction of Walter Barboza.

In São Paulo there are the *Serviço de Ortopedia e Traumatologia do Hospital Municipal* headed by Orlando Pinto de Souza, and the orthopaedic service of the *Hospital da Cruz Vermelha* under the direction of Azzi Leal.

Of interest is the *Clínica Ortopédica e Traumatológica da Santa Casa de Santos*, which has fifty beds and a very active accident service. It is headed by Emilio Navajas. It has a school for crippled and defective children, the only one of its kind in Brazil.

In the emergency government hospitals in Recife, Rio de Janeiro, and Porto Alegre, there are special sections with staffs of traumatic surgeons ready and equipped to care for fractures and other injuries of the locomotor system. The traumatic service of the emergency department of the Porto Alegre Hospital has modern equipment; the staff is headed by Sergio Cattani de Curtis.

CONTRIBUTIONS TO ORTHOPAEDIC SURGERY AND TRAUMATOLOGY

A number of original contributions have been made by Brazilian specialists to the literature of orthopaedic and traumatic surgery. The following are worthy of note:

Rezende Puech devised a surgical procedure for the treatment of paralytic talipes calcaneus.

Well known are the studies made by Godoy Moreira on the treatment of fractures of the neck of the femur, using a special lag screw for osteosynthesis. Godoy Moreira's trephine is a useful instrument for bone biopsies. The same author and collaborators have developed a new set of instruments and a technique for bone grafts, particularly for those of the so-called bicondylar type. From the same authors came an instrument for the fixation of the head of the femur in the osteosynthesis for fracture of the neck of the femur.

Domingos Define designed a model of a table for the treatment of fractures of the spine. He also developed a technique for the stabilization of the ankle joint in the paralytic foot.

Achilles de Araujo designed a table for the treatment of fractures of the upper limb.

Milton Weinberger made a valuable contribution to the traction of the fingers, by using a special device, which was adopted by Albee on his fracture table.

Flavio Pires de Camargo has been studying the technique of intramedullary osteosynthesis in the *Clínica Ortopédica e Traumatológica de São Paulo*, and has developed a new technique for fractures of the distal end of the femur.

Edmundo Batalha (São Paulo) has studied refrigeration anaesthesia and the technique of bone-grafting.

Luiz Gustavo Wertheimer (São Paulo) has made original studies on the innervation of the joints.

Lauro Barros de Abreu (São Paulo) has developed a standardized surgical signalling, which includes most of the instruments used in orthopaedic surgery,—that is, standardized the way of asking for instruments during the operation by special hand signs.

In the field of roentgenographic techniques as applied to the locomotor system, two works deserve mention:

Jany and Moretzsohn de Castro (São Paulo) have developed a practical technique for cineroentgenography for every moving part of the body. By photographing the image on a special fluorescent screen, using film hypersensitized with mercury vapor, these workers were able to get excellent motion pictures of moving organs at any target-film distance, in an illuminated room and with remote control. This will open an immense field in the study of kinetics. The apparatus is being manufactured in England.

Geraldo Guerreiro (São Paulo) has developed a technique for slow lateral exposures of the thoracic spine with the patient breathing. This erases the shadows of the ribs, leaving clear images of the vertebrae.

FIG. 7
The new *Clínica Ortopédica e Traumatológica da Universidade de São Paulo.*

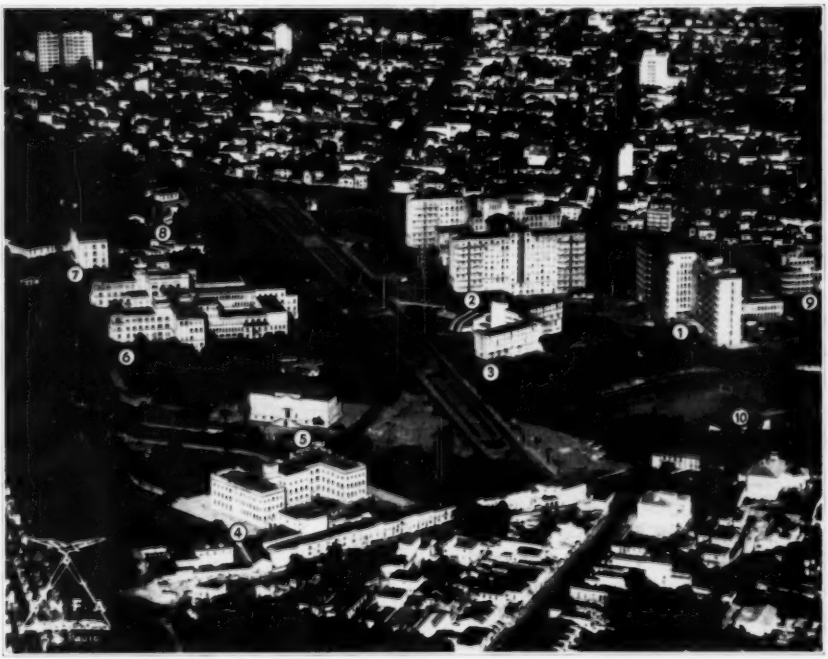

FIG. 8
Medical Center of the University of São Paulo. (*1* is the *Clínica Ortopédica e Traumatológica.*)

The scientific productions of Brazilian orthopaedic and traumatic surgeons have been published for the most part in three medical reviews: *Revista do Hospital das Clínicas* (São Paulo), *Revista Brasileira de Ortopedia e Traumatologia* (Rio de Janeiro), and *Arquivos Brasileiros de Cirurgia e Ortopedia* (Recife, Pernambuco).

Some subjects have been particularly well studied in our country. Congenital anomalies and malformations have been extensively studied by Brazilian orthopaedists. Among the numerous publications on the subject we shall mention those dealing with congenital dislocation of the hip joint, club-foot, and some of the more rare conditions.

Congenital dislocation of the hip joint in Brazil, as Puech emphasized, does not represent the problem it does in some European countries. Its incidence in our country is greater among those of foreign races who have lived for some time in our country, for instance among the Japanese. Despite this finding, the subject has received special attention from several authors, such as Domingos Define, Zander, Bomfin, and Bittar, besides those already mentioned.

The study of congenital club-foot and its treatment has long been a subject of interest. There was a symposium on this subject at the Seventh Meeting of the *Sociedade Brasileira de Ortopedia e Traumatologia* presented by Pinheiro Campos and Define Frascá. It was also the subject of a good monograph by Benjamin Salles and of a paper by Freitas da Gama of the *Universidade da Baía*. Finally there is the work of Nogueira Flores in which he included a review of the different methods of treatment used.

Among publications relating to the rarer congenital deformities, mention should be made of Kanan's *A disostose cleido-craneana e coxa-vara congênita*, Wertheimer's work on the coracoclavicular joint and limitation of movement of the shoulder joint, and Araujo's *Costelas cervicais*.

As to the metabolic diseases of bone, we must mention the work done by Ulhoa Cintra who wrote *Doenças ósseas metabólicas*, a widely illustrated work in which a new disease entity, a variation of Fanconi's syndrome, characterized by lack of the glycosuric element, has been described and the proper treatment has been outlined. Extensive research has been carried out by Cintra and his collaborators on the same subject. Magalhães Carvalho has published an excellent monograph on rickets in Rio de Janeiro. Another investigator in the field of bone diseases is Hermeto, Junior. Among his publications may be mentioned: *A paratiroidectomia na moléstia de Engel-Recklinghausen; Os processos de reabsorção óssea. Significação e consequências cirúrgicas; Forma mono-ostótica da moléstia de Engel-Recklinghausen; A frequência do ademona da parátireoide na moléstia de Engel-Recklinghausen*.

Obstetrical paralysis was presented by Pinto de Souza and Barros Lima at the Fifth Meeting of the *Sociedade Brasileira de Ortopedia e Traumatologia*. These authors published an excellent monograph on the subject. Recently Graner studied the patients treated in the *Pavilhão Fernandinho* during the last ten years with special attention to their follow-up, having in mind possible sequelae.

In 1939 Define published a valuable monograph on coxa plana, dealing with experimental studies made on rats. Dagmar Chaves also wrote on the same subject in 1948.

The subject of low-back pain has been carefully studied by Pinto de Souza, and Kanan has published a monograph on os purum bone grafts.

Bone infections, chiefly osteomyelitis and tuberculosis, represent some of the most frequently studied subjects in Brazil. Acute hematogenous osteomyelitis is common in Brazil, showing a higher incidence among the rural groups of children. Numerous are the studies carried out in this field, ranging from the use of antistaphylococcic vaccines to the modern antibiotics. Define in the *Pavilhão Fernandinho* and Camargo in *Clínica Ortopédica e Traumatológica* have published numerous writings, which, in addition to stressing the importance of aborting the disease with these agents, discuss the importance of different surgical techniques in the treatment of the sequelae. The report of Abreu and Ferreira presented at the Sixth Meeting of the *Sociedade Brasileira de Ortopedia e Traumatologia* should be mentioned.

The incidence of osteo-articular tuberculosis in Brazil is low, as compared with its incidence in European countries. This fact must be due chiefly to the pasteurization of

milk and to the factor of insolation, because in Brazil there is sun most of the year. Statistics show that tuberculosis is more frequent in the sea-shore cities, such as Recife, Rio de Janeiro, and Santos. Brazilian contributions to its study have been important, especially those of Pinto de Souza and of Sardinha who studied the use of streptomycin; of Altino who emphasized the diagnosis of tuberculosis by lymph-node biopsy; of Barros Lima and of Bomfim who studied the most frequently affected joints, as well as different methods of treatment.

Lacaz published in 1941 an invaluable monograph concerned with the study of mycotic articular lesions. In his *Estudo das micoses com tesões osteo-articulares* he presents a considerable number of cases, following systematic laboratory standards in the identification of the etiological agents. He comes to the conclusion that these osteo-articular lesions are rather common among us and do not present any specific roentgenographic or clinical picture. The most common mycotic bone infection in Brazil, according to his studies, is the actinomycotic mycetoma, with a preponderant localization in the foot. The etiological agent frequently found in this case is the *Actinomyces brasiliensis* (Lindenberg, 1909).

The abundant literature on the prophylaxis and treatment of infantile paralysis demonstrates the great interest in this disease in Brazil. Poliomyelitis is endemic in every state of the Union and in many of them it may occasionally occur in severe epidemic form. Pinheiro Campos, after a comparative study of the disease in the United States and Brazil, came to the conclusion that it is equally frequent in both countries.

Poliomyelitis was one of the official subjects of the Third Meeting of the *Sociedade Brasileira de Ortopedia e Traumatologia*, at which Godoy Moreira and Barros Lima presented a report on the treatment of its sequelae. Recently Marcondes de Souza and Bartolomei published the late results in 300 cases of surgical stabilization of the foot and muscle transplants at the knee in the treatment of the sequelae of infantile paralysis.

Besides the contributions already specified, we should also mention the following papers: Carvalho, about electrotherapy in the treatment of Heine-Medin's disease; Ferreira and Lazzareschi on tendinous transplants in hip-joint paralysis; Zander focused attention on alterations in statics in the course of treatment of total paralysis of the lower limbs, and Chaves analyzed the triple arthrodesis in the stabilization of the paralytic foot.

In the field of traumatic lesions of the locomotor system, many interesting papers have been published. The advantages of certain methods of treatment or contributions to several current techniques are brought to light from large series of cases.

Along with the considerable technical developments in every branch of medicine, the treatment of fractures has today become highly specialized. Several factors may change the prognosis regarding a given fracture, but the one which stands out as most important is the type of treatment employed. It is here that the skill of the traumatic surgeon makes a great difference. Familiar with every type of fracture as well as with all methods of treatment, he knows which will best suit the particular case. Another point which has a definite bearing on the outcome of treatment is the adequate surgical armamentarium for the treatment of trauma which he possesses and knows how to use to the best advantage of his patient.

Mention should be made of the chief Brazilian contributions in the field of traumatology in addition to those previously cited.

Many contributions on fractures of the femoral diaphysis have been made to the literature. This subject was chosen for discussion at the last meeting of the *Sociedade Brasileira de Ortopedia e Traumatologia*, opened and led by Lazzareschi and Weinberger. A word should be said about the contributions of Mario Jorge and, most recently, Pinto de Souza, Pinheiro Campos, Abreu, and also of Camargo and his collaborators.

In fractures of the leg, Batalha and his collaborators studied the end results in 3,000 patients treated in the *Clínica Ortopédica e Traumatológica da Universidade de São Paulo.*

Bipolar fixation with Kirschner wires was the procedure of choice. Correa do Lago also made a significant contribution on the same subject. Pinto de Souza and Bruno Maia's communications on fractures of the ankle joint are valuable contributions and treat the subject extensively. Fractures of the bones of the foot have been studied by Blessmann and Salles.

As to fractures of the bones of the forearm, the papers of Souza Ramos and Wertheimer and his collaborators should be mentioned.

Finally we must mention Achilles de Araujo's paper and Batista's monograph on traumatic lesions of the wrist, and Moraes's communications on styloiditis of the radius.

NOTE: The authors wish to thank Prof. Achilles de Araujo for information and photographs used in the account of the early history of orthopaedics in Brazil.

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THE DEVELOPMENT OF ORTHOPAEDIC SURGERY AND TRAUMATOLOGY IN CHILE

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In Chile, only during the last twenty-five years have orthopaedic surgery and traumatology taken their place as an important specialty different from general surgery. During the first half of this century, the most renowned surgeons of the period became the pioneers of this branch of surgery. Almost all of them had attended courses giving special training in European schools of surgery. The majority followed the teachings of French orthopaedists, and a few acquired their knowledge in Germany or Austria. It is due to French influence in our country that this specialty has been established mainly in children's hospitals, following the pattern of Prof. Ombredanne.

This paper will deal with the development of this branch of surgery in Chile and with the principal men who deserve credit for the importance it has today as a science in itself and as a harmonious synthesis of science and art.

Gregorio Amunategui (1868–1938), Professor of Clinical Surgery and Dean of the *Facultad de Medicina* of the state university, planned and founded the Chair of Orthopaedic and Children's Surgery. In 1909, it became a part of the *Hospital de Niños Roberto del Rio*. Prof. Eugenio Diaz Lira (1880–1945) was at that time at the head of it. He had been Prof. Amunategui's most efficient, dynamic, and brilliant collaborator, and had acquired his training in children's surgery and orthopaedics under Broca and Kirmisson, and in osseous tuberculosis at Berck sur Mer with Calot and Ménard.

To Prof. Diaz Lira belongs the credit of having started the specialty and set it in motion. As early as 1919, he gave optional courses as Extraordinary Professor (one who is not full professor). His training and outstanding ability gave to the specialty such prestige that the full professorship was established in 1929. His enthusiasm, his ability as a surgeon, his enterprising nature, and his fatherly love and kindness awakened an interest in the specialty, which acquired fundamental importance in the medical field and a most astounding growth.

With remarkable perseverance, Prof. Francisco Navarro (1872–1940), who occupied the Chair of Surgical Pathology (1910–1935), imparted great importance to traumatology. On retiring, he wrote the *Facultade de Medicina*, donating a sum of money to establish an annual award for the development and advancement of orthopaedic surgery, which he felt was the only branch of surgery which, in Chile, had not reached the stature of the other branches.

In 1925, the political developments of the country enormously influenced the sudden development and importance of traumatology through the many socialistic laws which were passed, providing medical assistance for workmen and employees. One law, No. 4055, for instance, providing insurance for industrial accidents, was passed during the presidency of that statesman, Arturo Alessandri Palma.

About 1930, several medical centers were established in different parts of the country to give special care to people crippled by industrial accidents, thus giving greater importance to orthopaedic surgery and creating an interest in plastic surgery of soft tissues.

Many and noted were those trained during these years in the Department of Orthopaedic and Pediatric Surgery; among them, Prof. Arnulfo Johow, who succeeded Prof. Diaz Lira, "the Master", and who is now serving at the same Hospital (*Hospital de Niños Roberto del Rio*) together with Prof. Ernesto Prieto and Eugenio Diaz B.

Hospital de Niños Manuel Arriaran, another center, growing out of the first, was established in 1920. It has been very important in the development and advancement of

the specialty. It has been directed by Agustin Inostroza, and among his collaborators have been Juan Gandulfo (1898–1932), A. Alonso, Cesar Izzo, and the author.

A new and particularly interesting orthopaedic center was established in 1945 at *Hospital de Niños Luis Calvo Mackenna;* here, there is splendid team work; the staff devote full time to the work.

The industrial accident law, No. 4055, has been useful as a basis for traumatological training through the entire country. It created an organization, the full development of which required twelve years and became a reality on December 7, 1937, the day of the establishment of the *Instituto Traumatologico de Santiago.* This institute occupies a modern building five floors high; the first two floors are used for an out-patient department, physiotherapy, and administration; the basement is used as a prosthesis shop, and the other floors for about 200 beds. Up to November 1, 1951, 194,000 patients had been treated.

FIG. 1

Professor Eugenio Diaz Lira (1880–1945)
First Professor of Orthopaedic Surgery at the *Universidad de Chile*

FIG. 2

Professor Francisco Navarro
(1872–1940)

FIG. 3

Dr. Juan Gandulfo
(1898–1932)

The head of the *Instituto* is Prof. Teodoro Gebauer; seventeen traumatologists collaborate with him, and there are five specialists from other branches of medicine. Prof. Gebauer received his degree in 1927. He has been Extraordinary Professor of Traumatology since 1938, having been a favorite assistant of Prof. Navarro and Prof. Opazo. He received special training in Europe (1928–1929), and took shorter courses in 1930 and in 1950; he has also been secretary of several South American medical congresses. About fifty traumatologists practising throughout the country have been trained by him.

In the organization, the development, and the advancement of the *Instituto Traumatologico,* Prof. Fernando Opazo, one of Prof. Navarro's students, deserves special credit. He was Medical Advisor; his reputation, high clinical standards, technical ability, and ideals have given the *Instituto* prestige as a first-class specialized center.

In the administration—that is, the regulations, finances, and equipment, as well as in the building of the *Instituto* even to its smallest architectural details—Mr. Francisco Perez Lavin, administrator for years, must be remembered. In the press, by lectures, and in scientific journals, he struggled to establish the monopoly of the Board of Insurance for

Labor Accidents (*la Caja de Accidentes del Trabajo*) for all the crippled workmen in the country as a state organization which, fundamentally, ought to work socialistically rather than as a commercial enterprise.

Due to the shape of the country, remarkably long and narrow, other centers have been founded, as follows: in Coquimbo, Valparaíso, Curico, Talca, Concepción, Temuco, and Osorno. All of them belong to the Board of Insurance for Labor Accidents, which at first depended largely on the *Caja Nacional de Ahorros*, a sort of monetary bank partly supervised by the State.

In bringing about the present growth of the specialty, Prof. Vittorio Putti, from Bologna, Italy, had a powerful influence, blending orthopaedics and traumatology into a broad, precise, and important concept, as the surgery of the locomotor apparatus. In 1936, he visited Chile and gave two scholarships; one was awarded (1936–1937) to the author and the other (1939–1940) to Cesar Izzo.

The contributions and the new ideas from this famous master's dynamic school have been spread throughout the country and over Latin America by the author both from the orthopaedic sections at *Hospital Luis Calvo Mackenna* and at *Hospital de Carabineros* (Police Hospital) from the traumatological section.

In this country the Central Board of Hospitals (*Servicios de Beneficencia y Asistencia Social*) controls almost all the hospitals; it has a splendid organization prepared to provide all the essentials. As an organization partly of the state, it gives hospitalization and treatment, under contracts previously enacted, to a great volume of patients who come under the social laws; it gives attention to the destitute, and in accordance with an agreement between it and the University of Chile, it contributes to medical teaching, which is conducted by professors appointed to hospitals in Santiago and Concepción. Due to this fact, one specialist is in charge of only a few beds, hence depriving orthopaedics and traumatology of a centralization which might prove beneficial in experimental work, in teaching a vast number of students, and in giving specialists certain standards.

In Santiago, with 1,500,000 inhabitants, 12,500 hospital beds are available, 10,813 belonging to the Central Board of Hospitals, 500 to military hospitals, and about 1,260 to private hospitals.

Excepting the *Instituto Traumatologico*, the entire number of beds available to patients with pathological conditions of the locomotor apparatus under treatment by specialists amounts to about 340. The thousands of people who are not injured in factories but on other jobs or who suffer from tuberculous osteo-arthritis must also be cared for in these beds.

Each of the six surgical clinics of the University of Chile (the state university) has qualified specialists in attendance.

In Concepción University there are also consultants both in orthopaedics and in traumatology, and next year this university may have a full Chair of Orthopaedics.

Valparaíso ranks high with a well equipped *Instituto Traumatologico* of about ninety beds. The chief is Manuel Rivera, who has trained many surgeons in the specialty who work not only in the *Instituto Traumatologico* with remarkable success but also in the various hospitals of Valpara´so.

The prosthesis shops in Santiago's *Instituto Traumatologico* in the *Hospital Roberto del Rio* and in the *Hospital Luis Calvo Mackenna* have contributed to the teaching and advancement of the specialty. A very important contribution has been that of one of these shops (*Ortox*) in which are made all appliances required in the surgery of the locomotor apparatus, including instruments, osteosynthetic devices, and immobilization apparatus. These are distributed to all parts of the country. This shop, created after the pattern of the shops of the *Istituto Rizzoli*, Bologna, Italy, has made many instruments and apparatus designed by Chilean surgeons. This shop aims to standardize the instruments needed by the specialty throughout the country.

The *Sociedad de Cirujanos de Hospital* holds meetings once a year lasting an entire week, to discuss the chief articles of the year; these articles are published in the Society's *Boletín*. Three years ago this Society joined the *Sociedad de Cirugía de Chile* in publishing *Archivos de la Sociedad de Cirugía*. The *Instituto Traumatologico* has occasionally published its work both in *Anales* and *Jornadas Traumatologicas*. *Hospital Roberto del Rio* has collected in its archives all the publications of the Department which have appeared since 1930. The specialty's most important advancement has resulted from the *Sociedad de Ortopedia y Traumatologia*, founded in 1949, because of the influence it has had on teaching, in creating laws and regulations for the practice of surgeons and technicians, and in giving specialized training to students and postgraduates.

Since not all publications of Chilean surgeons on orthopaedic subjects can be included in the bibliography, the following list includes only the theses accepted for the degree of Doctor of Medicine from the University of Chile.

THESES FOR DOCTOR OF MEDICINE OF THE UNIVERSITY OF CHILE

(*Arranged chronologically*)

Godoy, L.: El masaje y la movilización en el tratamiento de las fracturas. 1900.
Villarrael, M.: Estudio sobre la profilaxia de los accidentes ocasionados por el aire comprimido. 1904.
Reed, E.: Osteo-artropatía hipertrofiante. 1905.
Araos, L.: Tratamiento de las osteomielitis crónicas. 1906.
Herrera, L.: Tratamiento de las osteoartritis tuberculosas. 1906.
Sepulveda, J.: Amputación interescápula-toráxica. 1907.
Brito, A.: Estudio sobre las amputaciones osteoplásticas. 1908.
Cortez, C.: Estudio clínico sobre las atriciones de los miembros. 1908.
Lopetegui, F.: Fractura de la rótula y su tratamiento operatorio. 1909.
Molina, E.: Consideraciones sobre el diagnóstico y tratamiento del mal de Pott. 1910.
Canales, M.: Osteotomía, estudio de las enfermedades del pié y de la rodilla. 1910.
Labra, L.: La resección diafisiaria en la osteomielitis. 1911.
Urrutia, P.: Tratamiento ambulatorio y masaje en las fracturas de la pierna. 1911.
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Aguilar, L.: Micetoma o pié de madura. 1913.
Wood, J.: Tratamiento de las heridas articulares y de las artritis traumáticas por el método de Murphy. 1917.
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Fonck, R.: Luxación congénita de la cadera. Contribución al tratamiento no cruento. 1917.
Elguin, S.: Relación entre los vicios de reflexión y los vicios de posición de la columna. 1918.
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Sievers, H.: Contribución al estudio de las anquilosis y su tratamiento por la ionoterapia. 1921.
Pena, T.: Comentarios sobre injertos óseos vivos y autógenos. 1922.
Castro, H.: Contribución al estudio de la osteosíntesis. 1923.
Grez, A.: Osteosíntesis. 1923.
Beize, C.: Kinesiterapia en afecciones articulares. 1923.
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Humeres, A.: Contribución al estudio de las fracturas. 1926.
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Guasalaga, E.: Indicaciones de laminectomía en la fractura vertebral. 1927.
Contreras, A.: La simpaticectomía peri-arterial en los retardos de consolidación de las fracturas. 1927.
Cofre, A.: La osteoartritis tuberculosa en el medio hospitalario. 1927.
Miranda, M.: Contribución al estudio de las exostosis osteogénicas. 1928.
Tornero, L.: Tratamiento de la tuberculosis quirúrgica por el método de Finikoff. 1928.
Prieto, E.: Póliomielitis y su tratamiento actual. 1928.
Prayuox, B.: Fractura de la columna vertebral. 1929.
Herane, E.: El método de Lecene en la osteomielitis. 1929.
Gajardo, J.: Concepto actual de la artritis gonocócica y sus tratamientos. 1930.
Berman, L.: Contribución al estudio de la osteosíntesis temporal por el procedimiento del Profesor Ombredanne. 1930.

Escudero, E.: Apósitos de larga duración en las fracturas expuestas. 1931.
De La Maza, V.: Contribución al estudio del mal de Pott en la infancia. Operación de Albee. 1931.
Murray, R.: Contribución al estudio de la artritis focal embólica. 1931.
Berardi, L.: Enfermedad de Kümell Verneuil. 1931.
Jarpa, G.: Afecciones no tuberculosas de la cadera en el niño. 1931.
Azmora, J.: Osteomielitis y tratamiento con radioterapia. 1931.
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HALF A CENTURY OF ORTHOPAEDICS IN URUGUAY

BY DR. JOSÉ LUIS BADO, MONTEVIDEO, URUGUAY

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The development of orthopaedic surgery in Uruguay repeats in its general outlines the features which have characterized it in almost every country in the world. Its origins blend with those of general surgery.

For the purpose of outlining its development, it may be divided into two extensive periods. The first extends from the turn of the century up to 1935, thus covering a period of thirty-five years. The second covers the years from 1935 to 1950.

First Period: 1901-1935

In this first period, the practice of surgery of the locomotor apparatus was one of the many activities of the general surgeon. Treatment and teaching pertained to general surgery with special emphasis on children's surgery. There was, therefore, a general surgeon for adults and a children's surgeon, both of whom included in their sphere of activities treatment of bone lesions and trauma and teaching of orthopaedics and traumatology.

In the second period, from 1935 up to the present, an already specialized activity has sought to limit itself to surgery of the locomotor apparatus and of the various elements which constitute the organs of locomotion, with the designation of "surgery of the organs of locomotion". In its growth, this favorite daughter of surgery acquired a personality of its own, independent from that of the trunk from which it stemmed. In fact, surgery as a science, capable of facing all pathological problems and with ever-increasing progress, has not been able to retain its integrity, to the benefit of the solutions entrusted to it. Its sphere of action has broadened continually, and thus specialization has been born out of the innate power of progress which divides, not in order to weaken, but rather to strengthen the ultimate achievement. It has asserted itself as a phenomenon obeying natural reactions, and its appearance on the scene is independent of the will of man or of schools. And thus it is that today *ortopaedia* is considered "surgery of the locomotor apparatus", and the *ortopaedista* is a "surgeon". In its splendid maturity, it stands for much more than André endeavored to express by the name with which he baptized it in the eighteenth century. It is the surgery which comprises in its study and in its practice everything relative to a complex organic system, overflowing therefore the frame of the body which originally was supposed to limit its sphere. It is reconstructive surgery, plastic surgery, and the surgery of rehabilitation. Even more, it is a science and an art, born in a soil prepared for safe anatomopathological bases, for correct methods of investigation, and for rational therapeutic aims. In furthering the purpose already expressed by André's symbol, it concerns itself not only with *correcting* but also with *preventing* deformities, taking over in a definite manner the treatment of rickets and of

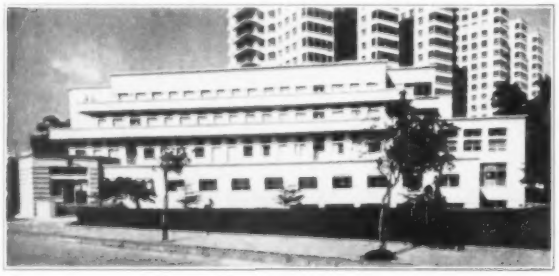

FIG. 1

View of the *Instituto Traumatológico*, Montevideo. At the rear may be seen the building of the *Hospital de Clínicas*.

traumatic lesions of the extremities. Orthopaedics cannot be separated from traumatology; they spring from the same roots; they feed from the same sources, and are trained with the same discipline; and the efficacy of this concept has been measured already, not only by the progress made in the field of instruction, but as well, and fundamentally, by the decrease in suffering, complications, and morbidity.

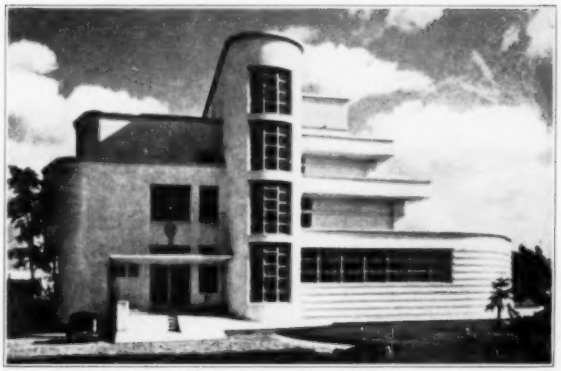

FIG. 2

Side view of the *Instituto Traumatológico*, Montevideo, showing the emergency entrance.

In the early years, at the turn of the century, the practice of orthopaedic surgery in Uruguay was not clearly defined, blending, on the one hand, with the practice of general surgery and, on the other, with children's surgery, and confined to a quite limited field of activity. In so far as it concerned the adult, its aim was the treatment of the most frequent traumatic lesions; concerning the child, its field was limited to congenital dislocation of the hip, club-foot, and osteo-articular tuberculosis in general.

FIG. 3

Operating room of the *Instituto Traumatológico*, Montevideo.

In 1897 one of the greatest surgeons of the second half of the century, Dr. Alfredo Navarro, was appointed professor of clinical surgery. He had drunk deeply from French sources and his professors, Tillaux, Kirmisson, and Teofil Anger, had imbued him with a particular interest in the diseases of the locomotor apparatus, as he evinced later in numerous papers of great value. Both in teaching and in treatment, he paid particular attention to certain lesions of the extremities. Coxa vara, flat feet, fractures of the wrist, dislocations of the carpus, Dupuytren fractures, and fractures of the spine were his favorite subjects; and the uniqueness of his concepts, together with the brilliancy of his exposition, earned him continental renown.

In the *Clínicas Quirúrgicas* the traumatic lesions most frequently studied were: dislocations of the shoulder, of the hip, and of the elbow, fractures of the spine, of the shaft of the femur and of the leg, fractures of the humerus and of the forearm; and their treatment was inspired in general by the ideas and concepts voiced in that epoch by the French school. Other affections of the locomotor apparatus, either of congenital origin or acquired, as a rule, were exceptional cases: club-foot, tuberculous osteo-arthritis which required resections and arthrodeses, tabetic arthropathies, and malignant tumors of the bone which demanded radical surgery.

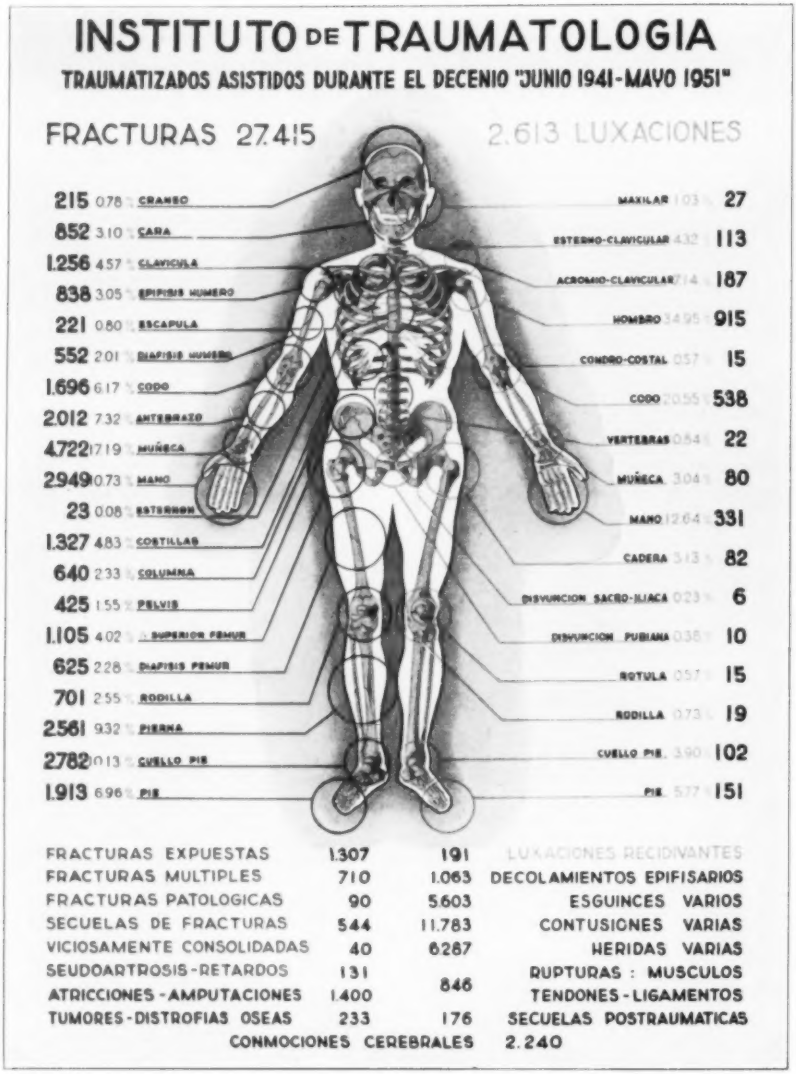

FIG. 4

Injuries treated at the *Instituto Traumatológico* during the ten-year period June 1941 to May 1951 included 27,415 fractures and 2,613 dislocations.

The teaching covering this type of lesions at the *Clinica Quirúrgica* was based upon general pathology, there being, of course, no specialized teaching.

In 1908, when the *Hospital de Niños Pereyra Rosell* was inaugurated, two wards were dedicated to children's and orthopaedic surgery, with a capacity of sixty beds, and Dr. Prudencio de Pena was appointed chief of that service, a position which he held for almost thirty years.

More or less contemporary with it, a service of children's and orthopaedic surgery was initiated at the *Hospital Pedro Visca* under the direction of Dr. José Martirené.

In the same manner that the general surgeons treated adults, the children's surgeons in these clinics treated the most frequently seen lesions of the locomotor apparatus: tuberculous osteo-arthritis, congenital dislocations of the hip, club-foot, rachitic or congenital deformities, and osteomyelitis.

In 1921 the *Facultad de Medicina* decided to create the Chair of Children's Surgery, which was filled for the first time in 1926, by Dr. Manuel Albo.

During the period extending from the turn of the century up to 1935, publications and papers—that is, an orthopaedic literature—were practically non-existent, with the exception of a few of Navarro's publications on the subject of physiopathology of the carpus and of the knee, and one on fractures of the spine which was of great value when considered from the point of view of symptomatology.

Second Period: 1935–1950

In 1935 Prof. Eduardo Blanco Acevedo established in the *Clínica Quirúrgica* a department designed for traumatology and orthopaedics, appointing Dr. José L. Bado chief of the Service. In that department, which included only twenty beds, the severely injured patients were treated, and in a precarious way everything related to the specialty was taken care of. A group of young physicians—Vázquez, Pedemonte, Caritat, and Cagnoli—gave their loyal and enthusiastic collaboration. The aims of teaching and practice of the activities in this Service were patterned after the school of the *Istituto Rizzoli;* its late Director, Prof. Vittorio Putti, must thus be considered the real teacher, the creating spirit of orthopaedics in Uruguay.

The efforts made evident during five years of work under those conditions resulted in the creation of an organization dedicated exclusively to the care and treatment of those with injuries of the locomotor apparatus and including also occupational or industrial accidents. This latter phase of the work was made possible by the collaboration of and an understanding with the *Banco de Seguros del Estado*, which in our country monopolizes everything relative to accident insurance. Thus it was that in June 1941 was inaugurated the *Instituto Traumatológico*, a dependency of the *Ministerio de Salud Pública*.

After a short time, the *Instituto* monopolized the care of the injured, thus accumulating, in the course of a few years, a fund of experience hardly equaled by similar institutions. The drawing in Figure 4 gives an approximate idea of the amount of work done in the course of ten years.

As an integral part of its activities, services of physiotherapy and rehabilitation, an out-patient department, prosthesis workshops, a plaster-cast department, both blood and bone banks, and other services were organized. Actually the record department now includes more than 72,000 case records and almost a quarter of a million roentgenograms. It can be truly stated that the *Instituto* is the birthplace of all the orthopaedic bibliography of the country.

In 1948 the publication *Anales de Ortopedia y Traumatología de Montevideo* was founded, publishing three issues yearly. In this journal the papers on the specialty are published.

In 1949 was founded the *Sociedad de Ortopedia y Traumatología de Montevideo*, at the monthly meetings of which papers on the affections of the locomotor apparatus are presented and discussed. This society is closely bound to the *Sociedad Latino Americana de Ortopedia y Traumatología* founded in Acapulco in 1948; the first Congress of this organization, held in December 1950 in Montevideo and Buenos Aires, was a fine expression of the development and progress of orthopaedics in the Latin American countries.

Other Services

Besides the *Instituto Traumatológico*, there are in Montevideo orthopaedic services connected with the Children's Surgical Clinic in the *Pereyra Rosell* and *Pedro Visca* hos-

pitals. The *Banco de Seguros del Estado*, which, as we have stated, monopolizes the service for the care of occupational accidents, has recently inaugurated a hospital destined exclusively for the care of such cases.

Teaching

In 1946 the Advisory Board of the *Facultad de Medicina* created the Chair of Orthopaedics and Traumatology which was filled by competitive contest in June 1951, Dr. José Luis Bado receiving the appointment. Henceforth these courses will be compulsory for all medical students.

Postgraduate Teaching

The *Facultad de Medicina* is organizing postgraduate courses of instruction and improvement in technique. It is felt that at some time in the future the degree of "specialist" will be conferred by the *Facultad*, upon completion of an advanced five-year course.

Social Projections—Social Legislation

For several years the orthopaedists of Uruguay have been aiming their efforts at winning legislation which would fill the needs of the handicapped.

Since 1942 there has been the *Asociación Nacional para Ayuda del Niño Lisiado* (National Association for Aid to the Disabled Child) which among its other enterprises has a school for the rehabilitation of handicapped children (spastics and those crippled by poliomyelitis) named "Franklin Delano Roosevelt" in memory of one of the greatest benefactors which humanity has ever had. There is also a legislative bill for *Seguro Social de Protección al Inválido* which, if definitely passed, would no doubt represent a great gain in that field.

The great majority of the papers on orthopaedics published in Uruguay belong to the *Escuela del Instituto Traumatológico* and already constitute a copious bibliography.

NOTE: It is with deep regret that we publish this article without the excellent bibliography prepared by the author. This is due to the inexplicable delay in the mails. It is hoped that this bibliography may be included in the October issue.

The Editor.

FIFTY YEARS OF ORTHOPAEDICS AND TRAUMATOLOGY IN ARGENTINA

BY DR. JOSÉ MANUEL DEL SEL, BUENOS AIRES, ARGENTINA

It is indeed a difficult task and a heavy responsibility both to outline the development of our specialty through half a century and to relate its history, without incurring mistakes and involuntary omissions. The reason for my having accepted this task is entirely due to the fact that I suggested the idea in a letter to the British Editor of *The Journal of Bone and Joint Surgery*, for the publishing and commentary of which I must thank Sir Reginald Watson-Jones.

The history of orthopaedics and traumatology is the history of the men who helped to build the specialty and of the institutions in which the specialty has been practised. It is an unquestionable fact that personal effort always preceded the more extensive organizations in which the work has been carried out, in an already established and smoothly running system, by increasing its quantitative and qualitative possibilities.

In the vast territory of Argentina (1,112,743 square miles), Buenos Aires was the leader of the movement, although later two other well known orthopaedic centers appeared,—Rosario de Santa Fé and Córdoba. The latter eventually became important nuclei and through their technical and scientific progress, together with the role played in association with Buenos Aires, have taken an important part in the spread of orthopaedics in the interior of the country by training capable specialists who organized centers in many other cities of this widespread country.

By sheer coincidence, the time spanned by our narrative includes two similar periods, which cover two distinct stages.

THE FIRST TWENTY-FIVE YEARS

At the beginning of the century, orthopaedic surgery did not exist in our country as a definite specialty. The first orthopaedic surgeon was Luis A. Tamini, an exceptional man, son and grandson of medical doctors, who was graduated in 1903. When appointed to direct the Mechanotherapy Section of the *Instituto Lacroze*, he became aware of the inadequacy of this type of treatment. In order to acquire the necessary knowledge which he could not obtain in his own country, in 1905 Tamini went to Europe, where he studied at the *Istituto Rizzoli*, Bologna, Italy. The head of this *Istituto*, at that time, was Alessandro Codivilla; under his leadership the young doctor became conversant with the different problems of his specialty. With this solid basis, Tamini later visited other European centers, and in Zürich, under Prof. Schultess, he made a thorough study of scoliosis and its treatment.

On Tamini's return to Buenos Aires, Marcelino Herrera Vegas, who had become aware of the importance of young Tamini's efforts, gave him his full support and placed him in charge of the orthopaedic cases of his Department of Clinical Surgery at the *Hospital de Clínicas*.

Later he entered the Surgical Department at the *Hospital Teodoro Alvarez*, on Roccatagliata's Service. Tamini took over this Department in 1910 and, although it was devoted to general surgery, he gave preference to orthopaedic cases.

Almost at the same time, but without exclusive specialization, a department was organized at the *Hospital de Niños* (Children's Hospital), at that time headed by Alejandro Castro. This great surgeon practised children's surgery and orthopaedics jointly, following the French school of medicine which was then the chief influence in Argentine medicine.

About 1912, the Department of Surgery at the *Hospital de Niños* had 360 beds, with 120 allotted to cases of bone tuberculosis. In this place Maximo Castro and Marcelo Viñas

FIG. 1
Luis A. Tamini
1877–1938

FIG. 2
Pedro Chutro
1880–1937

FIG. 3
Enrique Finocchietto
1881–1948

created a true school of orthopaedics and children's surgery where Rodolfo Rivarola, Manuel Ruiz Moreno, Carlos Lagos García, and Sara Satanowsky, as well as many others, received their training. These four practised orthopaedics and have published valuable papers on the subject. Rivarola and Lagos García died young, but Ruiz Moreno and Sara Satanowsky are now outstanding teachers under whose leadership numerous disciples have studied, who now constitute an important group of specialists within Argentine orthopaedics.

When Tamini left the *Hospital de Clínicas*, José M. Jorge and Castelfort Lugones, both assistants to Herrera Vegas, continued practising the specialty in the latter's Surgical Service.

Wishing to do justice to those who contributed to the development of orthopaedics in Argentina, Tamini, in his inaugural speech as holder of the Chair of Orthopaedics, recalled that "in the *Hospital de Clínicas*, Alejandro Posadas, that figure whose talent made him at an early age a Master in General Surgery, practised orthopaedics, and his teachings were followed by his favorite pupils: Sussini, Chutro, Roccatagliata, Arce and E. Finocchietto".

After the First World War had been declared in 1914, a certain number of Argentine doctors went to France; among them there were two who later became great teachers of Argentine surgery,—namely, P. Chutro and E. Finocchietto. Their fondness for orthopaedics unquestionably binds their names to the history of the specialty.

Pedro Chutro (1880–1937) had a real passion for teaching. He was one of the most brilliant professors of surgery in our country and undoubtedly the first teacher of surgical symptomatology. The experience he gained in the course of his time spent in the hospitals of France is to be traced in his lessons on clinical surgery and in his book on pseudarthrosis.

Enrique Finocchietto (1881–1948), also a disciple of Alejandro Posadas, was graduated in 1904, his thesis being on the subject of talipes equinovarus. He always had an inclination toward orthopaedics, although his extraordinary talent made him successful in every branch of surgery. He did his postgraduate work in Europe and later, during the First World War, became Senior Surgeon of the *Hospital Argentino* in Paris. With his ingenious spirit, he was constantly thinking of perfecting techniques, thus creating numerous and original apparatus and instruments, many of which were important contributions to orthopaedics. Through his efforts, the Department of Traumatology, with twenty-five beds, was founded at the *Hospital Rawson*.

Argentine orthopaedic surgery continued to develop, thanks to the individual efforts of the more capable, but nearly always in close relation to general surgery. To Tamini

is due the honor of having been the first in his time to practise it as a specialty to the exclusion of all others, thus setting the foundation for future development. Tirelessly he fought for the creation of a Chair of Orthopaedics at the Medical School, and once he gave up his promising chances of holding the Chair of Clinical Surgery rather than to lay aside the plan which he had decided to follow. Thus, owing to his insistence, in 1920, the Chair of Orthopaedics was created at the *Facultad de Ciencias Médicas de Buenos Aires*. Tamini was placed in charge and later, in 1923, became Professor. The seed had borne fruit, and Tamini held the Chair in a brilliant manner and with full authority.

FIG. 4

Prof. Putti and his first Argentine disciples. From left to right: Carlos E. Ottolenghi, José Valls, Guillermo Allende, Prof. Putti, Otaño Etchevehere, and Dellepiane Rawson.

Recalling this great man, José Valls has said: "The history of this Chair is short, but owing to the fact that Tamini held it, it is as alive and brilliant as the most favored of its sisters. Masters such as he do honor to a generation and to the School."

THE SECOND PERIOD

During its growth in the above period (1900–1925) Argentine orthopaedics had not acquired the prominence and importance which the specialty had won in Europe and North America from the beginning of the century, and especially after the First World War.

The isolated efforts of Tamini had certainly achieved the creation of a Chair in the *Universidad de Buenos Aires*, but in the rest of the nation and even in the capital itself, general surgeons continued to treat patients with disorders of the limbs, and did not look favorably upon the birth of a specialty which meant a decrease in a certain number of their patients.

Traumatology for a long time was in the hands of the general surgeons and not even Tamini resented this situation, which also existed in some European countries.

At this time Buenos Aires received the visit of Vittorio Putti, whose influence on orthopaedics in South America and especially in Argentina became the cornerstone of its development.

He gave a series of lectures which justifiably attracted much attention, shocked those in medical spheres, and aroused in some young surgeons an interest in the subject. When in the same year a postgraduate scholarship was created, the first scholar, José Valls, arrived at the *Istituto Rizzoli* in the month of December. Two years at the side of this exceptional teacher shaped the orthopaedic personality of young Valls, who, after visiting the main European clinics, accompanied his teacher on a trip to the United States of America to complete his preparation.

Upon his return to Buenos Aires, Valls was appointed Head of the Department of Orthopaedics and Traumatology at the local Italian Hospital. Valls owed this appointment not only to the name and influence of Putti and the prestige which he derived from him, but also to the good offices of the Hospital authorities and those of Marotta, Lenzi, Spada, and Marino. This Service, which started in 1926 with five beds and a male nurse under the direction of Valls, who was accompanied almost from the beginning by Carlos

FIG. 5

Enrique H. Lagomarsino
1900–1946

FIG. 6

Julio Piñeiro Sorondo
1903–1947

FIG. 7

Marcelo J. Fitte
1894–1949

E. Ottolenghi—his most outstanding disciple—has reached a development comparable only to that of the greatest specialized centers in North America and Europe. It can undoubtedly be said that this Department constituted the first Argentine school of orthopaedics and in it have studied and worked a large number of Argentine orthopaedic surgeons who now practise in different parts of the country, and numerous young doctors from neighboring and distant Latin American countries,—such as Chile, Peru, Venezuela, Colombia, Mexico, and Ecuador. Following Prof. Putti's concept, the Department at the Italian Hospital was really the first one devoted exclusively to orthopaedics and traumatology, where, as propounded by Codivilla, all the disorders of the locomotor system, spine, and limbs were treated.

Julio Dellepiane Rawson (1895–1930) was the second Argentine to obtain the scholarship to the famous Institution of San Michele in Bosco (*Istituto Rizzoli*, Bologna). Dellepiane Rawson acted for a time as specialist on the Service of Enrique Finocchietto and later devoted his efforts to organizing the Service of Orthopaedics and Traumatology at the *Hospital Rivadavia*. His untimely death, which prevented him from seeing the inauguration of this Service, deprived Argentine orthopaedics of a strong personality who would have formed an excellent school and produced first-class scientific work.

Valls and Dellepiane struggled for the recognition of the specialty among doctors and laymen and together they founded a private hospital devoted exclusively to orthopaedics and traumatology, which has acquired recognition among similar institutions.

Valls, in 1930, started the *Revista de Ortopedia y Traumatologia*, the first publication on orthopaedics in Latin America, in which have appeared papers from specialists both national and foreign.

After Dellepiane's death in 1930, Valls, together with Ottolenghi, Weber, and Lagomarsino, who had done postgraduate work at the *Istituto Rizzoli* under Putti, continued their efforts to spread and uphold the ideals of the specialty. With the help of Tamini, in 1936, they founded the *Sociedad Argentina de Cirugía Ortopédica*, which later, in 1949, became the *Sociedad Argentina de Ortopedia y Traumatologia*. This Society has, up to the present, published fifteen volumes of its *Boletines y Trabajos*.

Upon Tamini's death in 1938, Valls was appointed to the Chair of Orthopaedics at the University of Buenos Aires. At the same time he took over the old Department of the *Hospital Durand*, to which he has devoted all his enthusiasm, having resigned from the Chair of Orthopaedics at the *Facultad* of La Plata, and later from the Service at the Italian Hospital, in which he was succeeded by Ottolenghi.

The Chair at La Plata, founded in 1936, had Valls as its first Professor; Ottolenghi was in temporary charge of this post for some time. Upon Valls' resignation in 1940,

Enrique Lagomarsino was appointed to the Chair. His career was almost meteoric. Starting as Professor of Anatomy, he devoted himself to orthopaedics with all the zest of which he was capable. He organized and directed the Service of Traumatology at the *Hospital Militar* and introduced and drew up the rules which govern the specialty in the *Sanidad Militar* (Army Medical Corps). His spirit of the investigator led him to carry out important contributions to orthopaedics, one of the most outstanding possibly being the book *Fracturas del cuello de fémur* which he wrote in collaboration with Valls. Lagomarsino published important clinical and experimental papers on fractures of the spine and on the surgical anatomy of the hip and of the knee; in the latter, he had the excellent collaboration of Héctor Dal Lago. His sudden demise in 1946 at the early age of forty-six was a great loss to Argentine orthopaedics. In the Chair in La Plata, he was succeeded by Girardi.

Another blow was suffered with the death of Julio Piñeiro Sorondo, brilliant surgeon and enthusiastic orthopaedist. A man of outstanding talent, in a few years of practice he left the unmistakable seal of his personality. In the field of *Socorro Médico Aereo* (Air Medical Assistance) in orthopaedics and traumatology, he showed his experience and anxiety for the progress of the specialty by being the first to meet difficult situations in remote places of this country. He devised numerous surgical techniques, among which it is enough to mention the hindquarter amputation which he presented with Ferré. He laid the foundation of an excellent school which now continues under the direction of Rodolfo L. Ferré at the *Instituto Güemes*, in the Province of Buenos Aires.

Marcelo J. Fitte, who recently died at the age of fifty-five, was another man who made an outstanding contribution to Argentine orthopaedics. Soon after graduation, he showed great interest in the study of the diseases of the locomotor system, and went to Europe where he studied at different surgical centers, especially with Ombredanne. On his return to this country, he worked with Ruiz Moreno and E. Finocchietto. Fitte was a man of great scientific prestige, who carried out work of great value on scoliosis and poliomyelitis, two subjects on which he was considered to be an authority. For ten years he directed the *Servicio de Parálisis Infantil del Hospital de Niños* and was foremost in the struggle for recognition of the fact that these patients should be treated from the beginning and altogether by the orthopaedist.

At the same time, in the Departments of Surgery at the *Hospital de Niños*, orthopaedics continued to develop with the French characteristic of orthopaedics combined with children's surgery. Detchessarry, Alberto Lagos García and José E. Rivarola are three excellent surgeons who have been trained under Ruiz Moreno and Fitte.

Work at the *Casa de Expósitos* (a foundlings' home) is carried out along similar lines to that at the *Hospital de Niños*. There, under the leadership of Marcelo Gamboa, valuable new ideas have come to the fore, especially in the shape of Gamboa's contribution on talipes equinus and those of A. Salvati on problems of the congenital dislocation of the hip and of flat-foot.

Many other orthopaedic centers exist in Buenos Aires: in the *Centro Gallego* in charge of Felipe Oleaga Alarcón; in the French Hospital, under Roberto Paterson Toledo; in the *Hospital Rivadavia*, under Luis A. Weber; in *Hospital Argerich*, under Isidro Castillo Odena; in *Hospital Rawson*, under José A. Piqué; and a section of the *Instituto de Cirugía* (also *Hospital Rawson*) in charge of Leoncio Fernández and Americo Nunziata.

In the province of Buenos Aires, almost next door to the capital and within what is called the Greater Buenos Aires, there are to be found two important centers: the aforesaid *Instituto Güemes* in Haedo, and the Orthopaedic Department of the *Hospital Fiorito* in Avellaneda, directed by Pedro H. Garavano.

The *Sociedad Argentina de Ortopedia y Traumatología*, as previously stated, was founded in 1936. Tamini was elected its first President for a period of two years, and was succeeded by such well known figures in Argentine orthopaedics as José Valls, Marcos Steinsleger, Carlos Mosoteguy, Guillermo Allende, Carlos E. Ottolenghi, Oscar R. Marottoli and Luis A. Weber as presidents. Ottolenghi, Lagomarsino, Piqué, and Oleaga Alarcón have been secretaries and their efforts have contributed to the progress and development of the organization. The *Sociedad* publishes its monthly bulletins in which are printed the papers read and the subjects discussed at its meetings. Every year it is visited by world-renowned specialists who give lectures.

Since 1928, *La Asociación Argentina de Cirugía* has held a yearly congress which occasionally coincides with the *Congreso Interamericano*. Each yearly meeting is devoted to a subject on traumatology and orthopaedics, and up to the present the most important themes have been dealt with; the main speaker is always chosen from among the most outstanding specialists of Argentina or even from the neighboring countries. Exactly on its fiftieth anniversary (December 1950), Latin American orthopaedic surgeons held a brilliant Congress in the cities of Montevideo, Buenos Aires, and Mar del Plata; it was attended by more than 250 delegates who read contributions of positive value.

The *Revista de Ortopedia y Traumatología* was the first publication of its kind in the Spanish language. It was founded in 1930 by José Valls and, to this date, has published twenty volumes.

Argentine orthopaedics has a long list of publications to its credit. A large number of books and scientific papers have formed a true national literature which has also served as material for study and consultation in all countries where Spanish and Portuguese are spoken.

There are publications of value which have contributed to the progress of orthopaedics. According to their significance from the viewpoint of world orthopaedics, the following are worthy of mention: Valls and Ottolenghi in 1931 described a gland biopsy for the diagnosis of bone tuberculosis, the importance of which has been re-emphasized in the last few years.

Valls and Lagomarsino have contributed considerably to the technical progress of the treatment of fractures of the femoral neck by devising a procedure which has been adopted in many parts of the world. They published a book which constitutes one of the most comprehensive works on this subject.

The bloodless treatment of fractures, together with their surgical treatment, has attracted great interest in Argentina, but mention must be made of other interesting contributions on such subjects as: (1) skeletal traction, on which—after Finocchietto's and Zeno's papers—the most important publication has been that of Ottolenghi in a well documented and complete book; (2) the external fixation of fractures, especially as carried out by Valls' school; and (3) experience in intramedullary nailing, among which mention must be made of the papers by Jorge Valls, Castillo Odena, Dal Lago, Ferré, and Uslenghi.

The study of scoliosis has also been given preferential attention, the most important contributions having come from Fitte and his disciple Gonzalez.

On the subject of epiphysiolysis of the hip, the important paper by Muscolo presented to the *Congreso de Cirugía* is an excellent review of this subject.

The traumatic lesions of the knee have been the subject of important contributions from Finocchietto, Valls, Covaro, Lagomarsino, and Dal Lago.

Hydatid disease of the bone has also been favored by a large number of notable papers, and special mention must be made of the well documented thesis by Ivanissevich.

The study of bone tumors has been given special emphasis in different centers, but

to an even greater extent after Valls, Ottolenghi, and Schajowicz made aspiration biopsy known in our country through their important book, in which one of the chapters speaks of the spinal puncture with Ottolenghi's caliper.

Important contributions have also been made to the study of some tumors, especially the reticulum-cell sarcoma, epiphyseal chondroblastoma, giant-cell tumors, and the fibrous dysplasias. Among these, the most outstanding are the papers by Valls, Ottolenghi, Schajowicz, Mondolfo, Muscolo, Jorge Valls, Marottoli, Slullitel, Piqué, Brachetto-Brian, Copello, and Perruelo.

The organization of bone banks has engaged the interest of numerous specialists, and was one of the subjects dealt with at the *Congreso Latino-Americano*. Papers worthy of note on this subject have been written by Sgrosso, Marottoli, Valls, Muscolo, and Schajowicz; on refrigerated bone, by Van Domselaar and others; and on bone preserved in antiseptics.

THE TEACHING OF ORTHOPAEDICS

At Buenos Aires, La Plata, Rosario, and Córdoba are the four universities in which, up to the present, orthopaedics is taught as a specialty. Owing to its proximity to Buenos Aires, the sphere of influence of La Plata has been to a certain extent overshadowed by that of the great metropolis; its brief history has already been told.

In Buenos Aires, orthopaedics and traumatology is a subject studied in the last year of the curriculum. Teaching is both theoretical and practical. Some 600 students each year attend, during every morning for one month, this department at the Hospital where lectures are held, in-patients are examined, and operations are watched. The work of the professor is shared by assistant professors who receive pupils in their own Services in other hospitals; thus the student is able to gain experience in other surroundings and come into contact with the largest possible number of patients.

This style of teaching—which has so far proved effective, although it may be subject to criticism—is about to be modified and the specialty transferred to a postgraduate course. This postgraduate instruction has already been started by the *Escuela Quirúrgica de Post-Graduados del Hospital Rawson* and in the courses sponsored by the *Asociación Médica Argentina* and organized by Carlos E. Ottolenghi.

Rosario de Santa Fé

In this city, the second most important of the Argentine, the Chair of Orthopaedics was founded more than twenty years ago, and it has been held ever since by Prof. Marcos Steinsleger.

There are two other exceptional surgeons who have taken an active part in the development of the specialty in Rosario. The first one, Artemio Zeno, was a man who, with clear foresight, realized the need of separating orthopaedics and traumatology from general surgery; consequently, he was instrumental in guiding some of the young surgeons along these lines. The second, Lelio Zeno, brother to Artemio, a surgeon with a dynamic personality which has led him to practise successfully different branches of surgery, is one of the men who have contributed most to the development of traumatology in the northeast of Argentina. When still young, in 1931, he was requested by the health authorities in Moscow to create the first institute of traumatology in Russia, in accordance with a project which had been drawn up in collaboration with Prof. Sergius Judine, Professor of Emergency Surgery and Director of the Department of Surgery at the Sklyfasowsky Institute. L. Zeno produced great contributions to traumatology, of which one of the most important is the overhead skeletal traction in the treatment of fractures of the elbow in children. It is also worth mentioning the role he played in the spread of the

FIG. 8
The chief orthopaedic centers in Argentina.

specialty by translating into Spanish the first edition of Böhler's book.

Zeno, however, considered that traumatology was more intimately bound to emergency surgery than to orthopaedics. In his report to the Sklyfasowsky Institute, he tried to demonstrate this assertion and, although a number of people supported him in this point of view, there was much adverse criticism and many clamored in favor of the close connection which now exists between orthopaedics and traumatology. Even in the city of Rosario, time has shown the truth of the latter.

In addition to this Chair of Orthopaedics, two other orthopaedic schools have arisen which have become important centers. These schools are headed by Oscar R. Marottoli at the *Sanatorio Británico* and José A. Sgrosso at the Italian Hospital. A large number of young specialists have been trained in these two centers, many of whom have taken up practice in different cities of the country. The scientific contribution of Rosario's orthopaedists is vast and important; much of it has appeared in both national and foreign publications and also in its well known local journal, the *Anales de Cirugía de Rosario*.

Córdoba

This is an ancient and progressive city situated in the heart of the Argentine Republic. Its brilliant history during the Colonial Period is partly due to the fact that the first Argentine university was founded there. It has been called the "Learned City" because of this and because of its proverbial contributions to science.

It may be said that the history of orthopaedics in Córdoba begins in 1925, when Juan Martin Allende, then Professor of Surgery, visited the *Istituto Rizzoli*, and on his return suggested to his brother Guillermo the idea of specializing in orthopaedics. In 1927 Guillermo Allende won a scholarship to the *Istituto Rizzoli* and since then he has practised this specialty to the exclusion of all others. However, it was not until 1940 that the Chair at the University was founded; this was awarded to him by competition and is still held by him.

Numerous specialists have studied under Allende, who, in addition to the fundamental knowledge which he possesses on the subject, is a brilliant surgeon and teacher. Many of his pupils have located in different centers throughout the country, and others are still

associated with him at the *Hospital de Niños*, which may be considered one of the most important orthopaedic centers in Argentina.

In 1947, Córdoba founded its own *Sociedad de Ortopedia y Traumatología*, where the valuable scientific productions of this city are presented. Some publications on the work of Allende and his pupils have appeared in *The Journal of Bone and Joint Surgery*. Apart from those of this school, we should like to mention J. Zarazaga's papers on bone circulation and numerous contributions on infantile orthopaedics, and Carlos de Anquin's important publications on painful shoulder and brucellosis, the latter being a serious regional problem in Córdoba.

FIG. 9

Central Hospital, Mendoza (rear view), where an emergency fracture center was organized in January 1944 to treat over a thousand injured people.

Orthopaedics in our country has progressed thanks to personal efforts and to the close contact which has always been maintained between the men who have been leaders in the specialty. Thus the work, developed under control and exchange of ideas, has been able to establish orthopaedics and traumatology as a definite specialty and show that, although the value of the individual is important, it is organization which allows for constant improvement and the institutions which endure.

The progress of orthopaedics is consistent with the high level of Argentine medicine and the extraordinary excellence of its schools of anatomy, physiology, and surgical technique, where a large number of Argentine orthopaedists have studied. It is only fair to mention here the important contributions made by Belou (Buenos Aires) and Fracassi (Córdoba) to the knowledge of intra-osseous circulation.

In spite of the geographical situation of this great country, Argentine orthopaedic surgeons have always been in close contact with surgeons in this specialty all over the world. Argentines have always been travellers. In the beginning there was a strong influence from Italian, French, and German schools, and that is why our orthopaedists have always been outstanding in the bloodless aspect of the specialty and, consequently, the techniques of reduction and plaster, together with skeletal traction, have reached a degree of perfection not easily surpassed in other countries. Later, and especially in the past few years, in view of the closer and almost permanent contact with the United States of America and Great Britain, operative orthopaedics has developed with an ever-growing impetus.

From the beginning, Valls became aware of the importance of organization. Upon his return from Italy, Valls brought with him a technician from the *Istituto Rizzoli*. First with Dellepiane Rawson and Ottolenghi, and shortly afterward with Lagomarsino, he insisted that the specialty, to be most efficient, had to be carried out through teamwork. After his visit to Vienna in 1937, he studied the possibility of bringing to our country a pathologist, a disciple of Erdheim, and in the following year Fritz Schajowicz entered Argentine orthopaedics, to the progress and development of which he has contributed in a large measure.

Undoubtedly this cooperation and the division of the work has improved the production of Argentine orthopaedics. Recently Osmond-Clarke has said: "It is now almost impossible for any one individual to keep pace with the literature, and still less to engage

in the practise, of every facet of this branch of surgery; and, as experience has matured, there has been an increasing tendency to specialize within the specialty. . . ." This is an indisputable fact, the application of which represents positive progress. In a center as important as Buenos Aires, with a population of 3,500,000 (5,000,000 in Greater Buenos Aires), the close contact among the specialists allows for a subdivision of work. Valls for many years has cherished the idea of creating a great orthopaedic institute with a traumatological center within the municipal boundaries, but this unity of organization is impossible for the time being because of the present-day existence of a department of orthopaedics in each hospital.

Hospitals for convalescent and chronic cases, with some isolated exceptions, no longer exist. Rehabilitation centers, which have developed to an extraordinary degree in other parts of the world, have not yet abandoned the old patterns of physiotherapy and mechanotherapy.

The fundamental failure lies in the fact that in fifty years of practice of this specialty a national orthopaedic scheme has not yet been outlined. The orthopaedists who are practising in the interior of the country have always to rely upon their own efforts. The Department of Traumatology in the city of San Juan is one of the few exceptions, although there are orthopaedists, not only in cities of the importance of Mendoza, Tucumán, and Bahía Blanca, but also in some more distant points such as Salta, Resistencia, and Comodoro Rivadavia.

On the occasion of disasters of great magnitude which have made necessary the medical assistance for a large number of injured people, the solidarity of Argentine doctors, as well as other South Americans, has shown itself to be strong. When, in January 1939, the earthquake of Chillán (Chile) took place, a large number of Argentine specialists crossed the Andes in order to assist the wounded. Piñeiro Sorondo went by plane on the same day, and later on a large contingent led by Ottolenghi carried out a task which will hardly be forgotten in the sister republic. In January 1944 there was a truly catastrophic earthquake in San Juan (Argentina). A city of 80,000 lay practically in ruins. The number of dead was never accurately estimated, but it was calculated at 10,000. Immediate assistance was carried out by the local doctors, with the help of others from Mendoza, who arrived that same night. On successive days there came a large number of specialists in traumatology from all over the country and from Chile and Uruguay. Countless injured and survivors were sent to Mendoza, the largest number of which were admitted to the magnificent *Hospital Central* which had recently been finished and had to be immediately opened for that purpose. With true foresight, the Director of the Department of Hygiene, Eugenio Cialli, entrusted the whole organization of the treatment of the injured to José Valls. Valls, in collaboration with Ottolenghi, Lagomarsino, Oleaga Alarcón, Piqué, Múscolo, Jorge Valls, Petracchi, and with the help of the local doctors Padín, Danza, Notti, and Mas, and others from Rosario, such as Sgrosso and Didier, looked after the wounded according to a coordinated plan, using all the resources of traumatology.

On April 16, exactly three months after the earthquake, when only slightly over 100 of the original 1,200 patients still remained in the hospital and after the last bone suture and skin graft had been carried out, Ottolenghi handed the building back to the local authorities. This painful yet interesting experience shows what can be done by true organization of both work and equipment.

In my letter to the British Editor of *The Journal of Bone and Joint Surgery**, when recalling the contribution made by Argentine and Latin American orthopaedics to the general progress of the specialty, I mentioned only the technical papers and contributions on bone pathology; but, although we are proud of what has been accomplished up to this moment, we are far from considering what has been achieved as a definite goal.

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Ottolenghi, in an interesting medico-philosophical talk which he gave a few years ago, emphasized the necessity of giving an impulse to research and the division of work.

Scientific progress and its benefits belong to humanity, and it is because of this that we must strive to abolish boundaries and isolationism. Restriction to one's own language is the chief barrier which must be overcome by all the means available.

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A SHORT HISTORICAL SKETCH OF ORTHOPAEDIC SURGERY IN CUBA

BY DR. PEDRO SÁNCHEZ TOLEDO, HAVANA, CUBA

Orthopaedic surgery in Cuba was performed by general surgeons until 1904, when Dr. Enrique M. Porto created the first dispensary and ward service at the *Hospital Nuestra Señora de las Mercedes*, while Dr. Armando Guerrero established another at the *Hospital Número 1*. After studying with Sayre and Whitman in New York, Dr. Porto devoted himself exclusively to orthopaedic surgery, whereas Dr. Guerrero practised it as a part of general surgery.

In 1916 Dr. Alberto Inclán started his work at the *Hospital Mercedes* as a loyal collaborator to Dr. Porto, and in 1920 he created a similar service at the *Hospital Municipal Freyre Andrade*.

When in 1925 a Chair of Orthopaedic Surgery was created at our University, Dr. Inclán was chosen to occupy it. Some time later he returned to the *Hospital Mercedes*, where, with the aid of the other members of the department, particularly Dr. Rafael Peñalver, he established a well organized service; this was really the first adequate orthopaedic service in our country.

Later, various services of this kind were organized by surgeons who had been specially trained at the *Hospital Mercedes* or at foreign universities.

In January 1933, Dr. Alberto Inclán founded the *Revista de Cirugía Ortopédica y Traumatología*, which was to become the official organ of our society.

The *Sociedad Cubana de Ortopedia y Traumatología* was founded on March 6, 1944. The society conducted its work under the presidency of Dr. Inclán until December 1949, when an election entrusted the direction of the association to a board of directors. Their efforts were greatly stimulated by the First Congress of the *Sociedad Latino-Americana de Ortopedia y Traumatología* held in Montevideo and Buenos Aires in December 1950.

At the present time the *Sociedad* has forty-eight active members, and its organization has developed to such an extent that it maintains services in every hospital in Havana and in most provincial capitals, as well as an institute of orthopaedic surgery.

TREATMENT OF NON-UNION IN COMPOUND FRACTURES WITH INFECTION *

BY MATHER CLEVELAND, M.D., AND EDWARD M. WINANT, M.D., NEW YORK, N. Y.

From the Orthopaedic Service of St. Luke's Hospital, New York

The treatment of ununited fractures has always been a major challenge to the surgeon. When complicated by the presence of infection, the non-union becomes infinitely more resistant to surgical correction. The cases to be discussed in this study were not cases of delayed union; they were true ununited fractures. All except one of these were either infected as the result of a compound wound or secondarily infected following surgery for the original fracture.

This is a small series of patients. Fortunately these serious problems of bone replacement in the presence of infection are not often encountered on an orthopaedic service. In view of the constantly large number of industrial and automotive accidents among civilians and the greatly increased number of compound fractures from various wounding agents among members of the armed forces, it seems important to record and reemphasize methods of bone and skin replacement with concomitant control of infection. This technique is not new or original; however, we have found it to be highly successful.

TABLE I

Treatment	Number of Patients
Antibiotic therapy	
Systemic	10
Local	2
Incision and drainage of abscess	6
Removal of foreign bodies, screws, plates, and silk	8
Sequestrectomy	5
Débridement or excision of infected bone	3

Ten patients were included in this study. In nine of the ten, the lesions were infected and drained at some time, either before or during the time they were under our care. The average time between fracture and bone-grafting was three years; the shortest time was seven months, and the longest was fifteen years. Five of the ten fractures were simple; five were compound fractures which became infected as a direct result of the original injury. Of the five simple fractures, one was a fracture through an old site of osteomyelitis in the femoral shaft which resulted in reactivation of the old infection, while three became infected as a result of previously attempted surgery at other hospitals, and accordingly through surgery became compound fractures.

From these brief statistics it is clear that these cases presented three distinct problems: first, control of existing infection; second, obtaining an intact integument of a quality as good as possible; and third, securing union of the fracture.

Infection

Before any definitive bone surgery was considered, every effort was made to arrest infection. The various procedures undertaken and the number of patients to whom each was applied are shown in Table I.

As a result of the treatment, infection was considered to be arrested in seven of the nine patients with infection. In two other patients, bone-grafting was done in the presence

* Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 20, 1951.

of persistent drainage. However, of the seven patients in whom infection was believed to be controlled, there were only two in whom the wounds healed by primary intention following bone-grafting. The other five required additional operative procedures as follows: removal of foreign material, three cases; sequestrectomy, four; and skin-grafting after operation, three. Healing of the wound was finally obtained in all of these cases.

Treatment of Associated Soft-Tissue Damage

Aside from the evidence of infection, the fact that forty-one operations had been performed on these ten ununited fractures before the operation to be described should give some indication of the abundance of scar tissue and resulting diminution of blood supply encountered in all of these cases.

Three of nine draining wounds healed by secondary intention with antibiotic therapy. Four required débridement with attempted delayed closure of the wounds. Of these, two were successful and eventually healed, while two failed to heal prior to bone-grafting. The remaining two patients required pedicle skin-grafting procedures in order to obtain an intact integument through which surgery could be initiated. Both of these skin grafts were successful.

While every effort was being made to control infection and to secure adequate skin coverage, the question of bone replacement or grafting was under consideration, and in some instances this procedure was carried out simultaneously.

Types of Bone-Grafting

Numerous surgical procedures have been recommended in the treatment of ununited fractures. Many are based on the principle of rigid internal fixation in one form or another. Various types of metal plates, screws, and massive cortical-bone grafts have been suggested and used with varying success. The authors believe that the massive cortical graft is slow to become revascularized, and infection would result in complete sequestration so that the entire procedure would have to be repeated.

In this series we have used multiple chips and ribbons of fresh autogenous cancellous iliac bone. These were obtained from the anterior portion of the ilium on the same side as the fracture. The anterior four-inch portion of the ilium was exposed subperiosteally on both the inner and outer plates of the ilium as far as the anterior inferior spine. The ribbons of bone were cut parallel to the crest of the ilium by means of an osteotome and were as thin as the continuity of the full length of the graft would permit.

These grafts were placed in abundance about the ununited fracture. Usually no attempt was made to excise the fibrous tissue between the fractured ends of the bone. The cortex proximal and distal to the fracture line was partially removed to promote bleeding and to produce a raw surface. The ribbons of iliac bone were then placed in barrel-stave fashion around the fracture site. In two patients in whom draining sinuses persisted, bone grafts were kept away from the draining area. These multiple cancellous grafts resemble a severely comminuted fracture, which usually heals more readily than does the complete cortical fracture without comminution.

Immobilization

Immobilization of the fracture is as important in the management of these fractures as the control of infection, the care of the soft-tissue injuries, and choice of the correct type of bone-grafting. No one method can be advocated. Metal plates and screws, skeletal or skin traction, and circular plaster-of-Paris dressings were all used. When screws or metal plates were employed, they were removed as soon as it was believed they had served their purpose. Five of the fractures were stabilized by the use of circular plaster-of-Paris casts. One was placed in traction and three had internal metal fixation. In one of the latter the screws were removed one month after operation because infection had developed.

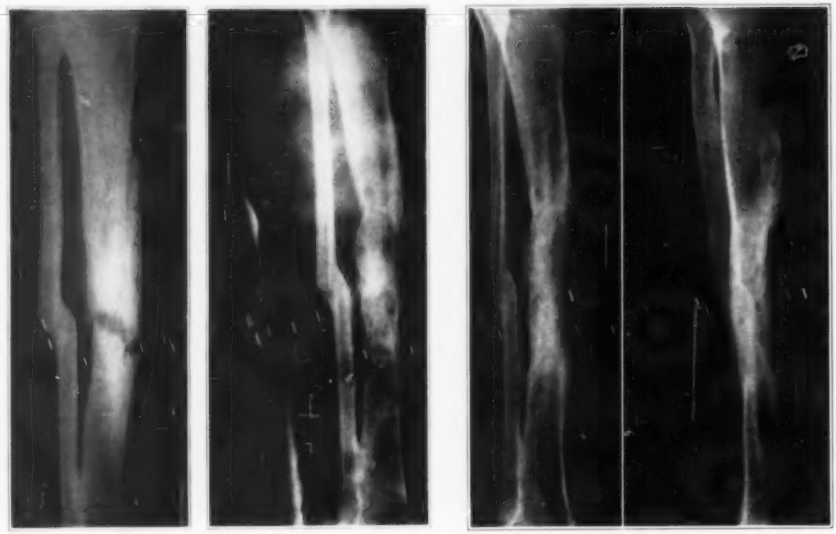

FIG. 1-A FIG. 1-B FIG. 1-C

Fig. 1-A: L. H. Roentgenogram made June 22, 1940, revealed non-union of the tibia two years after fracture. Two tibial-bone grafting procedures and transplantation of the fibula had been performed.

Fig. 1-B: June 1942. Consolidation of multiple ribbons of fresh cancellous iliac bone with early union of fracture three months after operation.

Fig. 1-C: June 1946. Anteroposterior and lateral roentgenograms four and one-half years after iliac-bone grafting. The iliac bone has become incorporated in the tibial shaft, the medullary canal has re-formed, and there is solid bony union.

In another the plate was removed four months after operation, and in the third the fixation was left *in situ*.

A brief presentation of five of the ten patients follows:

CASE 1. L. H., a thirty-year-old woman, sustained a compound fracture of both bones of her right leg in November 1938. She had had four operations prior to the iliac-bone grafting. Two of these were massive tibial onlay grafts and a third was a transplantation of the ends of the fibula into the tibia. A Thiersch graft was applied to the anterior crural region four years after bone-grafting, following excision of the scar.

The limb was immobilized in a toe-to-groin plaster-of-Paris circular dressing for a period of six months after the iliac-bone grafting procedure. This patient also had had immobilization in plaster-of-Paris circular dressings after the previous operative procedures, but, in spite of this prolonged immobilization, the patient had knee motion of 180 degrees of extension and 95 degrees of flexion. Ankle motion to 100 degrees of dorsiflexion and 120 degrees of plantar flexion was possible when the patient was last seen, on January 9, 1951.

Roentgenographic Studies

A roentgenogram (Fig. 1-A) made June 22, 1940, two years after her fracture, showed non-union following the second tibial-bone grafting and transplantation of the fibula.

A roentgenogram made in June 1942 (Fig. 1-B), three months after the iliac-bone grafting, showed evidence of early union. Anteroposterior and lateral roentgenograms (Fig. 1-C) were made four years and three months later, in June 1946. The iliac bone had become incorporated into the tibial shaft, and the medullary canal had re-formed. There was bony union which has remained solid.

CASE 2. M. P., forty-three years old, fell under a subway train on November 10, 1945. She sustained a compound fracture of the left femur and simple fractures of the humerus, ribs, and skull, with laceration and avulsion of the tissues of the posterior aspect of the left thigh. This patient had two months of skeletal traction, after which internal fixation was attempted with inadequate plates and screws and without reduction of the fracture. She reached our hospital with an infected compound ununited fracture, which was draining profusely.

An anteroposterior roentgenogram (Fig. 2-A) made May 10, 1946, showed the plating of the femur

FIG. 2-A

FIG. 2-B

Fig. 2-A: M.P., May 10, 1946. Non-union of the femur six months after fracture and four months after attempted internal fixation with dual bone plates.

Fig. 2-B: May 31, 1946. Immediately after removal of fixation.

FIG. 2-C

FIG. 2-D

Fig. 2-C: February 1947. Two months after multiple ribbons of autogenous cancellous iliac bone had been placed along the medial aspect of the femoral shaft to bridge the fracture.

Fig. 2-D: April 1951. There is consolidation of the multiple bone chips with solid bony union four and one-half years after bone-grafting.

done at another hospital and non-union four months after operation. The plate and screws were loose; drainage at this time was profuse. Another roentgenogram (Fig. 2-B) was made on May 31, 1946, immediately after the screws and plate had been removed.

FIG. 3-A FIG. 3-B FIG. 3-C

Fig. 3-A: J. F. B., August 1946. Non-union of tibia three years after fracture.
Fig. 3-B: May 1947. Six weeks after iliac-bone grafting.
Fig. 3-C: October 1948. Union with partial bridging of bone one and a half years after grafting.

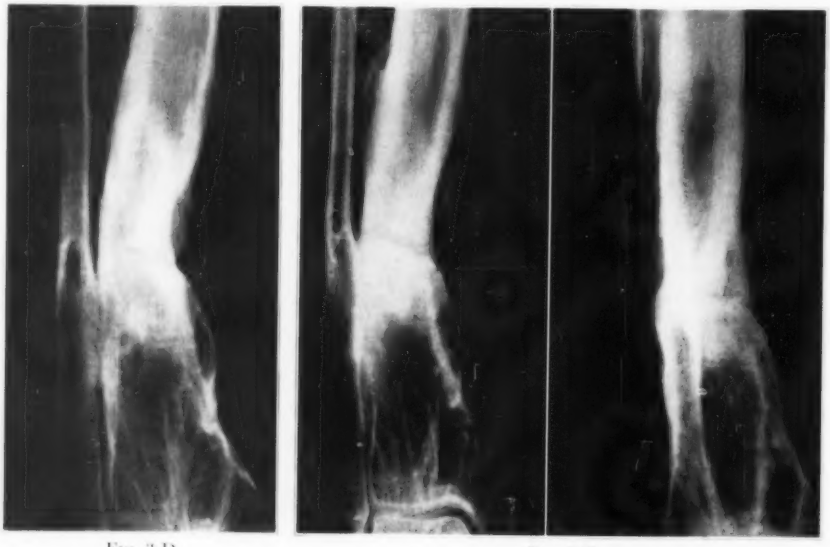

FIG. 3-D FIG. 3-E

Fig. 3-D: February 1949. Union and re-forming of medullary canal twenty months after bone grafting.
Fig. 3-E: February 1951. Anteroposterior and oblique roentgenograms four years after iliac-bone grafting, showing solid union.

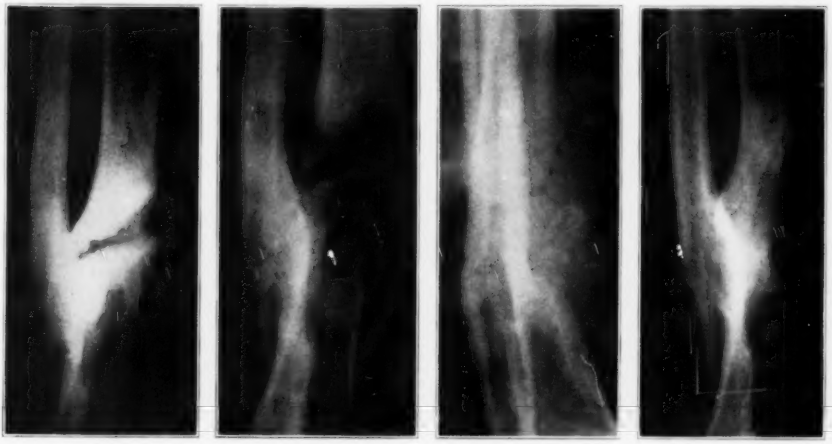

FIG. 4-A FIG. 4-B FIG. 4-C FIG. 4-D

Fig. 4-A: J. H., February 1947. Ununited fracture of the tibia fifteen years after injury, with sclerotic infected bone ends.
Fig. 4-B: May 1947. Defect in tibia following excision of infected sclerotic bone.
Fig. 4-C: June 1947. Defect filled with multiple autogenous iliac-bone chips six weeks after operation.
Fig. 4-D: June 1948. Solid bony union with new medullary canal one year after grafting.

Seven months after removal of the screws and plate, draining persisted and there was no evidence of union. At this time iliac-bone chips were placed about the medial side of the fracture site. A roentgenogram (Fig. 2-C) was made on February 17, 1947, two months after the iliac-bone grafting. Four and one-half years later, in April 1951, the roentgenogram (Fig. 2-D) showed consolidation of the multiple iliac chips with solid bony union. The medullary canal showed evidence of re-forming.

After the iliac-bone grafting, the patient was immobilized with skeletal traction on a Thomas splint with a Pearson extension apparatus for five months. She was then ambulatory in a long brace with a pelvic band which she wore for an additional six months. Motion of the joints adjacent to the fracture was as follows: knee motion limited, flexion to 90 degrees, with full extension; excellent hip motion, which was limited at 70 degrees of flexion as compared with 40 degrees in the opposite hip. Aside from this, hip motion was normal. The patient was last seen on April 26, 1951.

To sum up, in this case an osteomyelitis developed following a compound fracture of the left femur which failed to unite. Fifteen months after the original injury the ununited fracture was treated by grafting with multiple iliac-bone chips in the presence of an active infection. The fracture united in five months, and the sinus healed in six months. Full weight-bearing was permitted after nine months, but the following month an induration developed about the old drainage site in the left thigh. This was resolved with complete bed rest and 300,000 units of penicillin daily for one week. When last seen, four and one-half years after operation, the patient was asymptomatic and the fracture had remained healed.

CASE 3. J. F. B., thirty-four years old, sustained multiple fractures, including a compound fracture of the right tibia and fibula, in an airplane crash in 1943. During the next three and one-half years fourteen operations were performed on the right leg, but all failed to secure union of the fractured tibia.

She came under our care at this time and we found that, in addition to the non-union, the skin, although healed, was extensively scarred and in bad condition. Before bone surgery was undertaken, a cross-leg pedicle skin graft was successfully performed. Six weeks later, in April 1947, two large iliac grafts were placed across the fracture site and were fixed with screws. A large quantity of iliac chips and ribbons of cancellous bone was placed about the fracture site. After operation there developed a slough of skin one inch wide and two to three inches long, and the grafts and screws lay exposed. This was lateral to the pedicle skin graft. A culture from the wound yielded colon bacillus. The screws were removed, and a number of small sequestra were discharged from time to time, but the fracture united and the wound healed. It was five months before the

patient was permitted weight-bearing with a long brace, and it was thirteen months before the wound healed completely. The wound had remained healed when the patient was last seen.

FIG. 5-A

FIG. 5-B

Fig. 5-A: J. L., April 1947. Non-union of the femur, marked angulation, and overriding of the fractured fragments one year after fracture.

Fig. 5-B: November 1947. Four months after placing iliac-bone grafts along medial aspect of the femur.

FIG. 5-C

FIG. 5-D

Fig. 5-C: February 1949. Solid bony union with marked deformity and shortening.

Fig. 5-D: September 1949. Six months after excision of lateral spicule of bone from proximal fragment.

This patient's limb was immobilized in a plaster-of-Paris circular dressing following the iliac-bone grafting operation. The cast extended from the tips of the toes to the upper portion of the thigh and was maintained for seven months, after which the patient wore a long brace for two years. When last seen, on February 27, 1951, the patient wore a below-the-knee brace; at that time, she had full knee motion with limited ankle motion, dorsiflexion to 110 degrees, and plantar flexion to 125 degrees.

If a single cortical-bone graft had been applied, this would have sequestrated with a flare-up of the infection. Since union of this fracture was tenuous and since there was obvious atrophy of bone distal to the fracture, this very active patient is still wearing an ankle brace.

Roentgenographic Studies

Roentgenograms made on August 26, 1946, (Fig. 3-A) showed non-union of the tibia after fourteen operations; infection was also found to be present. Roentgenograms (Fig. 3-B) made in May 1947, six weeks after the operation, showed the iliac-bone grafts with two cortical iliac strips fixed by five screws with multiple chips and ribbons of iliac bone between. The cortical strips were too bulky, besides being unnecessary. In October 1948, one and one-half years after grafting (Fig. 3-C), there was union with a partial bridge of bone. In February 1949 (Fig. 3-D), twenty months after iliac-bone grafting, there was union with re-establishing of a medullary canal.

FIG. 5-E

March 1951. There is solid union fifty-nine months after fracture and forty-four months after the iliac-bone grafting.

The anteroposterior and oblique roentgenograms (Fig. 3-E) made on February 27, 1951, four years after bone-grafting, showed solid union.

CASE 4. J. H., thirty-nine years old, suffered a compound fracture of the right tibia and fibula in 1931. During the fifteen years following his accident he had had five operations on his tibia, performed at other hospitals. In May 1947, the patient entered St. Luke's Hospital with a draining sinus and an ununited fracture of the right tibia. A débridement of the infected bone was performed, followed by a split-thickness skin graft three weeks later. This healed, and after eight weeks iliac-bone grafts were placed in the defect in the right tibia. The wound broke down after the operation and continued to drain slightly for the following six months. A pedicle graft was then placed at the skin defect over the right tibia after infection had been controlled as far as possible. This was almost entirely successful and additional "pinch" grafts were placed around the granulating edge, which healed completely one year following the bone-grafting performed at this hospital. This fracture healed approximately seven months after bone-grafting and remained healed until the patient's death from infectious hepatitis three years later.

The patient's limb was placed in a plaster-of-Paris circular bandage extending from the tips of the toes to the upper portion of the thigh for a period of five and one-half months after operation. The last note on his chart before his death indicated that there was no restriction of knee motion, but ankle motion was limited from dorsiflexion of 100 degrees to plantar flexion of 125 degrees. The patient died December 21, 1950.

Roentgenographic Studies

A roentgenogram made on February 14, 1947, (Fig. 4-A) showed the ununited fracture fifteen years after injury with sclerotic infected bone ends. There was a draining sinus at this time. The roentgenogram made on May 11, 1947, one day before bone-grafting (Fig. 4-B), showed the defect resulting from excision of bone in preparation for iliac-bone grafting.

The roentgenogram made on June 21, 1947, (Fig. 4-C) showed the defect in the tibia filled with iliac

chips six weeks after bone-grafting. The final roentgenogram made June 3, 1948, (Fig. 4-D) one year after the iliac-bone grafting, shows a new tibial shaft with medullary canal.

CASE 5. J. L., fifty-one years old, suffered a simple fracture of the left femur on April 27, 1946. An open reduction was performed, and fixation was by plate and screws. Weight-bearing was permitted eleven weeks following this plating. Angulation developed and, in July 1946, a second open reduction was performed, with removal of the plate and insertion of a tibial bone graft. Subsequently an infection developed which required two débridement procedures. All of these operations had been performed prior to his admission to St. Luke's Hospital.

The patient entered St. Luke's Hospital in April 1947, with an ununited, markedly angulated fracture of the femoral shaft. Drainage had ceased temporarily. We were unable to improve the position of the fracture by manipulation. In July 1947, multiple small iliac-bone grafts were placed across the angulated fracture site. The wound drained persistently for two months without sequestration of bone chips. An abscess of the posterior aspect of the thigh was drained one month after operation; drainage of this area continued for seven months. Periodically there was also slight draining from the wound through which the iliac-bone chips had been inserted. The fracture united eight months after bone-grafting. A year and a half after bone-grafting, the prominent lateral spicule on the proximal fragment was removed. The final result was shortening of three and one-half inches. The patient became fully weight-bearing, with a lift on the heel and sole of his left shoe, and returned to his regular job as a salesman.

After the iliac-bone grafting procedure the patient was immobilized in a double hip spica plaster-of-Paris dressing for a period of nine months, followed by a single hip spica plaster dressing for one month. He was last seen on March 5, 1951, at which time he showed marked limitation of knee motion. There was extension to 180 degrees, and flexion to 170 degrees. Motion of the hip was 90 degrees of flexion and 180 degrees of extension. No notation was made regarding internal and external rotation, abduction, or adduction.

Roentgenographic Studies

A roentgenogram made on April 15, 1947, (Fig. 5-A) showed non-union of the fractured femur with marked angulation and over-riding of the fractured fragments one year after the fracture.

On February 28, 1949, (Fig. 5-C) there was solid bony union with marked deformity and shortening and with a subcutaneous spicule of bone along the lateral aspect of the thigh. This laterally projecting spicule of bone was excised (Fig. 5-D).

A final roentgenogram made March 14, 1951, (Fig. 5-E) showed union fifty-nine months after the fracture and forty-four months after iliac-bone grafting.

RESULTS

It would convey a false impression to say that in nine of these ten cases there was union of the fracture, healing of the soft tissues, and arrest of the osteomyelitis. In spite of improvement in surgical procedures and in spite of administration of antibiotic agents, many of these patients have had recurrent flare-ups of infection.

There was one failure in this series. This was a patient who had had osteomyelitis of the femoral shaft in childhood and had suffered two subsequent fractures of the femur with reactivation of the infection. We failed to arrest this infection and to obtain fusion of the grafts to the fractured fragments. A disarticulation of the hip was performed twenty months after his admission to the hospital. We regretfully performed this mutilating surgery after trying unsuccessfully for those twenty months to control the infection and to secure union.

Of the nine cases in which union of the fracture was obtained as a result of iliac-bone grafts, there were only three in which the wound healed *per primam* and remained healed without a recurrence of infection. In the other six there was exacerbation of the infection, necessitating additional sequestrectomies. Removal of screws was necessary in one case. Additional skin-grafting was required in three cases; two of these were pedicle grafts and the third a Thiersch graft. Most of these procedures were carried out before there was solid bony union of the fracture. Nine patients with united fractures of the femur or tibia are now fully weight-bearing and all of them have returned to their normal occupations. All of these patients have been asymptomatic for a period of one to five and one-half years. The longest period of hospitalization was twenty months; this was in the case which was a failure and in which a hip-joint disarticulation was performed. The shortest period of hospitalization was two months. The average period was seven months.

CONCLUSIONS

A method of bone grafting has been used successfully in nine of ten difficult cases of ununited fractures, in eight of which infection was present.

Multiple autogenous cancellous iliac-bone grafts are advocated for this procedure, because they are rapidly revascularized and are readily incorporated into the host bone. They do not tend to sequestrate in the presence of infection.

Adequate treatment of associated soft-tissue wounds and infection is most important.

Our procedure has been: (1) to attempt to control the infection; (2) to replace devitalized scar with adequate skin; (3) to proceed with bone-grafting.

DISCUSSION

DR. LEROY ABBOTT, SAN FRANCISCO, CALIFORNIA: In the first paragraph of their paper, the authors state: "The cases to be discussed . . . were not cases of delayed union; they were true ununited fractures . . . infected as a result of a compound wound or secondarily infected following surgery for the original fracture". This statement is highly significant, because it indicates the important role played by infection in causing non-union and the necessity of preventing infection in the early treatment of fractures.

The danger of infection exists in all compound fractures. In the majority, however, primary healing of the wound can be secured by early, thorough d'bridement, delayed primary closure, immobilization, and the use of penicillin. This is the lesson learned from our experience in World War II. Furthermore, internal fixation, especially with metal plates, is to be avoided. The use of the latter is frequently followed by infection, devitalization, loss of bone substance, and non-union. The subsequent history of many of these patients treated with internal metal fixation is one of repeated operations which require the further application of bone grafts as well as some additional form of internal fixation to hold the grafts in place. These secondary operations are not infrequently followed by a flare-up of the infection with loss of the graft, further sequestration of bone, and persistence of the non-union.

It is in the treatment of such a complicated condition that the writers have stressed the need for adequate drainage, removal of sequestra, infected bone, and scar, and for plastic procedures to close the skin before definite treatment is attempted to secure union by bone-grafting. The writers indicate that the type of graft employed is of great importance. They contend that in the presence of infection massive cortical grafts will sequestrate and non-union will persist. On the other hand, grafts of cancellous bone show rapid incorporation with the host bone. In infected areas, they do not tend to sequestrate.

The authors' successful results in ten cases of non-union by the use of cancellous bone as a grafting material support earlier work done by a group of us at the University of California Medical School. Our results were recorded in 1946[a] and 1947[b]. The experimental work reported in the second article was done by my associate, Dr. Edwin Schottstaedt, under a grant from the National Research Council. From these experiments and from clinical observations, we concluded that cancellous bone possesses a high degree of osteogenetic power and that its loose structure permits early and thorough revascularization. Cancellous bone is highly viable even in the presence of infection, and especially if used with penicillin, whereas cortical bone consists largely of an inert substance which seldom survives infection and is generally extruded from the wound. Even with cancellous bone the site of the union between the graft and the parent or host bone is weak and may fracture. Therefore, protective splinting is essential until consolidation has occurred. In the shaft of long bones, this takes place slowly. In some of our cases of ununited fractures of the femur or tibia, complete consolidation of cancellous bone, with the formation of a medullary canal, required periods extending beyond one and one-half years.

As was pointed out by the authors, union can be anticipated in these infected fractures by the use of cancellous bone grafts. This union is no guarantee against flare-ups of infection which may cause temporary disability. However, the value of the procedure has been demonstrated by the authors of the papers presented. In nine out of the series of ten cases of non-union of the femur or tibia, full weight-bearing was restored, with a return to normal occupation in each instance. Dr. Cleveland and Dr. Winant are to be commended for their excellent management of this group of difficult cases. Their splendid and meticulous study of these patients has enabled them to point out the fundamental principles which will provide a satisfactory answer to a problem that has hitherto been a most difficult one to solve.

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(*Continued on page 590*)

EXPERIMENTAL STUDIES IN THE TRANSPLANTATION OF WHOLE JOINTS*

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The transplantation of homogenous whole joints is not new in orthopaedic surgery. Judet [4, 5], in 1908, and Axhausen, in 1912, described the histological changes that occur when homogenous whole joints and half joints are transplanted subcutaneously in rabbits, rats, and dogs. Erich Lexer, as early as 1909, replaced the proximal end of the tibia in a human subject with a corresponding bone from a recently amputated leg. In other cases he resected entire knee joints and replaced them with knee joints from amputated limbs. Although evidence of aseptic necrosis and degeneration was present in most of these transplantations, function remained acceptable and essentially painless in a surprising number of his patients. May and Tuffier also performed homogenous whole-joint and half-joint transplantations clinically with some degree of success. This procedure, however, has not found general acceptance. There are obvious technical difficulties and until recently there has been the seemingly insurmountable problem of having a satisfactory homogenous graft available at the time it is needed. With the advent of the bone bank [2, 12], the possibility of whole-joint transplantation assumes a new importance. If bone and cartilage can be successfully preserved and later transplanted, why should it not be possible to preserve and transplant an entire joint? The present investigation was undertaken to study the feasibility of such a procedure.

The problem presupposes that it is possible to transplant an entire joint successfully without introducing the factor of the joint's being homogenous and the factor of storage. The first objective, therefore, was to investigate the feasibility of autogenous whole-joint transplantation.

Dogs were used as experimental animals and the left knee joint was selected for study. The operative technique consisted in exposing the proximal third of the tibia and the distal third of the femur by subperiosteal dissection (Fig. 1-A). The patellar tendon together with a fragment of the tibial tuberosity was removed and the quadriceps retracted medially (Fig. 1-B). The tendon of the extensor hallucis longus and the attachment of the gastrocnemius to the femoral condyles were divided. The femur and tibia were then divided in step-cut fashion. The entire knee joint, including the collateral ligaments, the cruciate ligaments, and the menisci, was then lifted free from its bed. The synovial membrane and articular capsule were excised except in the region of the collateral ligaments. The knee joint was then replaced in its original bed and internal fixation was secured either by the use of screws which passed through the step cut, or by means of wire sutures (Fig. 1-C). The patellar tendon was reattached, the extensor hallucis longus tendon was resutured, and the other muscle attachments were held in approximation with the bone surface by suturing the periosteal tube over the bone. A plaster spica was applied for a period of two weeks to allow for wound healing. It was then removed and the dog was allowed to begin weight-bearing on the affected extremity at will.

According to strict terminology, this is a replantation rather than a transplantation, but it was not feasible to transplant one of the large joints to a new location in the same animal, and the effect of the technique described is comparable to a true autogenous transplantation.

The early results were encouraging, and as it was evident that at least two years must be allowed to elapse before end-result evaluation, two other series were started: a series

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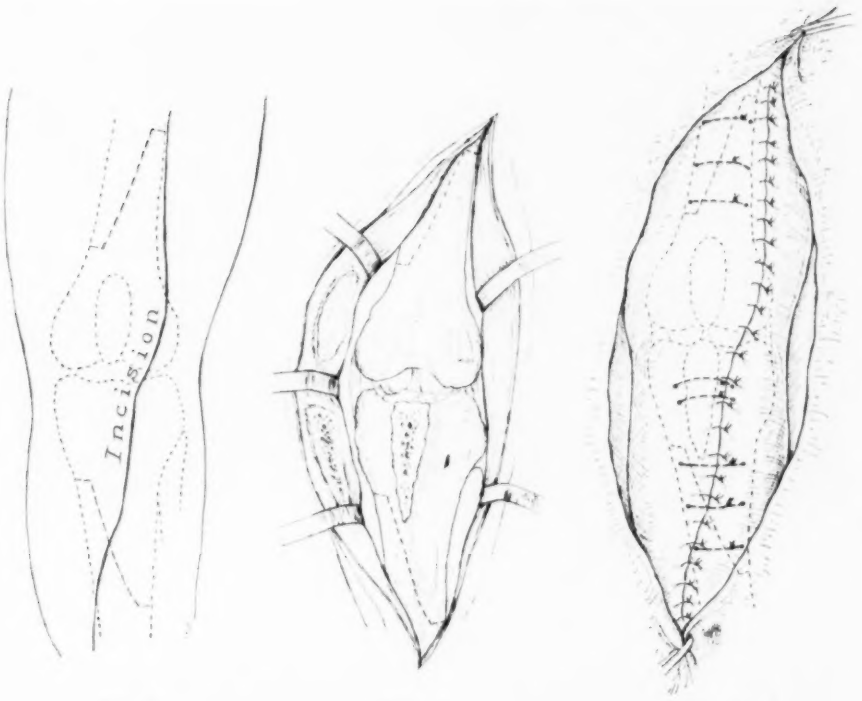

FIG. 1-A FIG. 1-B FIG. 1-C

Technique employed in transplanting the knee joint.

with delayed homogenous grafts and a series with direct homogenous grafts. In the series with delayed homogenous grafts, the knee joint which was removed was placed in a deep-freeze unit with aseptic precautions, and the joint was replaced by a similar homogenous joint which had been stored at −20 degrees centigrade for a period varying from one day to several weeks. In the series with direct homogenous grafts, two animals were operated on simultaneously, and the knee joints were transferred from one to the other.

A total of 129 dogs have been operated on by the technique described. Of course, a large number of these animals were lost in perfecting the technique. Other animals were lost because of the usual laboratory difficulties with distemper and diarrhoea. A few of the wounds became infected, and when this occurred, the animals were removed from the series and sacrificed. The animals were also sacrificed when the graft fractured, and at one period when the animals were being handled by inexperienced *Dieners* there were a number of such cases. In spite of these difficulties, fifty-six dogs have survived and are satisfactory for study; eighteen were treated with autogenous grafts, nineteen with delayed homogenous grafts, and nineteen with direct homogenous grafts. Roentgenograms have been obtained at regular intervals, and the animals have been sacrificed at intervals varying from one day to two years, so that the histological changes might be followed.

Animals in the series with autogenous grafts have been followed as long as two years. Functional results are routinely excellent. The animals begin to bear weight about four to six weeks after the operation, and within two to three months will run, jump, and play, apparently with no pain. Roentgenograms show that the step cut unites in four to six weeks and that the bone appears to have essentially normal structure. The joint space is

FIG. 2-A

FIG. 2-B

Autogenous knee-joint transplantation with a two-year follow-up. Operation was performed August 2, 1948; the animal was sacrificed July 27, 1950.

Fig. 2-A: Roentgenograms made September 2, 1948, one month after transplantation. The plaster spica was removed two weeks after operation and the animal was bearing weight on the affected extremity at the time this x-ray was made.

Fig. 2-B: Roentgenograms made March 21, 1949, eight months after transplantation. There is solid union at the sites of osteotomy and the bone appears viable.

FIG. 2-C

FIG. 2-D

Fig. 2-C: Roentgenograms made November 30, 1949, sixteen months after transplantation. There is a slight mottled area of resorption in the proximal end of the tibia, and there is narrowing of the joint space medially, but the joint has been fairly well preserved.

Fig. 2-D: Roentgenograms made July 27, 1950, two years after transplantation. The joint is well preserved, with only minimal narrowing of the joint space medially. Mild osteo-arthritic changes are present, but the bone structure appears essentially normal. Function at the time this x-ray was made was excellent. The animal walked, ran, and played with almost no limp. Motion of normal knee: angle of greatest extension, 175 degrees; angle of greatest flexion, 30 degrees. Motion of transplanted knee:

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FIG. 2-E

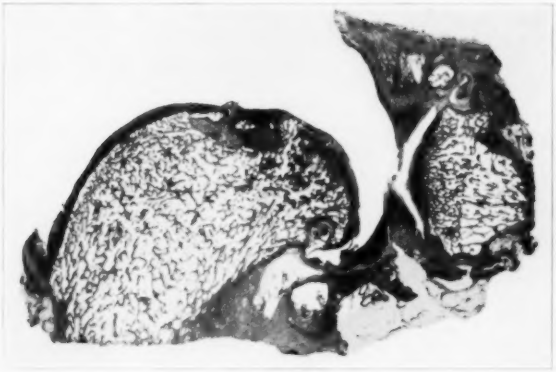

FIG. 2-F

FIG. 2-G

(Fig. 2-D *continued*) angle of greatest extension, 155 degrees; angle of greatest flexion, 60 degrees.

Fig. 2-E: Photograph of the knee joint at autopsy, July 27, 1950, two years after autogenous transplantation. The cruciate and collateral ligaments, the menisci, and the articular surface of the tibia have essentially normal gross appearance. There are superficial erosions of the articular surface of the femoral condyles.

Fig. 2-F: Longitudinal section (× 2.1) through the lateral femoral condyle and the weight-bearing portion of the tibia. (Hematoxylin and eosin stain.) The meniscus is covered to more than one-half its thickness with new fibrocartilage. The articular cartilage is necrotic in the weight-bearing area of the femur but viable deep in the patellar groove. It is covered superficially with a connective-tissue pannus and new fibrocartilage. There is a compression fracture in the central weight-bearing area of the femur, healing by scar tissue and fibrocartilage. The articular surface of the tibia is almost entirely viable. The spongiosa of both femur and tibia has been replaced and is viable throughout. The marrow is yellow-red except for a small area under the compression fracture where it is fibrous. The cortical bone is well reorganized.

Fig. 2-G: Transverse section (× 4.3) through the tibial step cut. (Hematoxylin and eosin stain.) The cortical bone, spongiosa, and marrow are normal throughout.

well maintained, and only comparatively mild arthritic changes have been observed during the course of these experiments. At autopsy, the joints have shown excellent preservation of the articular surfaces, menisci, and collateral ligaments. To be sure, in most specimens there is evidence of some arthritic change, but this has not been important in this series.

The histological picture is quite uniform and follows the well-known sequence of events seen in aseptic necrosis with creeping replacement[10]. Signs of necrosis first appear in the marrow, which by the end of the first week is almost entirely necrotic. Replacement by new fibrous-tissue ingrowth begins at about seven days and is complete by four weeks. Gradually, the new fibrous tissue is converted to a normal myelogenous and fatty marrow. In the spongiosa and cortical bone, the osteocytes appear viable for four to seven days before pyknosis and degeneration occur. Eventually, however, all of the osteocytes in the massive portion of the graft (that is, that portion of the graft which consists of the articular end of the shaft) die. Appositional new-bone formation appears at three to four weeks and

FIG. 3-A

FIG. 3-B

Delayed homogenous knee-joint transplantation with a sixteen-month follow up. The operation was on August 23, 1949; the animal was sacrificed on December 26, 1950. Technically, there was a rather poor fit at the femoral step cut.

Fig. 3-A: Roentgenograms made September 22, 1949, one month after transplantation. Plaster spica had been removed two weeks previously. The animal began weight-bearing about October 1, 1949.

Fig. 3-B: Roentgenograms made December 14, 1949, four months after transplantation. The joint is fairly well preserved, but there are mottled areas of diminished density in the proximal portion of the tibia with sclerosis in the weight-bearing area.

FIG. 3-C

FIG. 3-D

Fig. 3-C: Roentgenograms made August 17, 1950, one year after transplantation. Changes similar to those seen in avascular necrosis are apparent. A compression fracture involving the tibial weight-bearing area is present.

Fig. 3-D: Roentgenograms, December 19, 1950, sixteen months after transplantation. Marked degenerative changes are present in both femur and tibia. The structure of the bone in the step-cut areas, however, appears normal. Function at the time this roentgenogram was made was surprisingly good.

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FIG. 3-E

FIG. 3-F

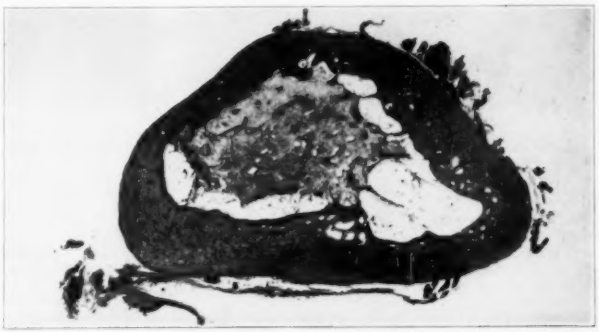

FIG. 3-G

(Fig. 3-D *continued*) The animal had only a slight limp. Motion of the normal knee: angle of greatest extension, 160 degrees; angle of greatest flexion, 50 degrees. Motion of the transplanted knee: angle of greatest extension, 155 degrees; angle of greatest flexion, 60 degrees.

Fig. 3-E: Photograph of knee joint at autopsy December 26, 1950, sixteen months after delayed homogenous transplantation. The ligaments and menisci appeared normal, but there was marked fibrillary degeneration and erosion of the articular surfaces. The tibial articular surface was depressed.

Fig. 3-F: Longitudinal section (× 2.1) through the lateral femoral condyle and the weight-bearing portion of the tibia. (Hematoxylin and eosin stain.) The meniscus is largely replaced by fine-fibered connective tissue and fibrocartilage. The articular surface of the femur is necrotic and eroded. The weight-bearing area is covered with pannus and new fibrocartilage. Elsewhere, the femoral articular surface is covered with dense connective tissue. The tibial articular cartilage is absent and the articular surface is covered with dense scar tissue being transformed locally into fibrocartilage. The marrow is necrotic under the weight-bearing area of the femur but elsewhere it is composed of viable fibrous tissue. The spongiosa is dead in both femur and tibia but undergoing active resorption in the femur. The cortical bone is largely dead in both femur and tibia but some reorganization is taking place.

Fig. 3-G: Transverse section (× 4.3) through the tibial step cut. (Hematoxylin and eosin stain.) There is excellent bony union and the site of the osteotomy is not definitely discernible. Revascularization of the Haversian systems is complete. The cortical bone of the host (lower left) is largely viable with a few dead tracts, while the cortical bone of the graft (upper right) is largely dead.

creeping replacement proceeds until reorganization is complete; this occurs by six months in the tibia and by nine months in the femur. The articular cartilage remains normal for the first fourteen days and then shows slow extension of necrosis beginning superficially and peripherally to the weight-bearing surface of the joint. Scattered areas of the articular cartilage remain viable, while that part which undergoes necrosis is covered by a pannus which later forms fibrocartilage. Surviving islands of cartilage cells undergo proliferation and contribute to the replacement. The menisci undergo necrosis and are replaced by fine-fibered connective tissue which in later specimens present stages of transformation to fibrocartilage. In the region of the step cuts, union by fibrous callus is present at seven days and bony union is present at one month. Osteocytes in the cortical bone of the graft are viable although some pyknosis occurs up to fourteen days. Partial necrosis then occurs, but many tracts remain viable in this smaller step-cut area of the graft. Complete reorganization so that the host could not be differentiated from the graft was present in this series within six to nine months (Figs. 2-A to 2-G).

FIG. 4-A

FIG. 4-B

Delayed homogenous knee-joint transplantation with a two-year follow-up. Operation on June 23, 1949; the animal was sacrificed on July 31, 1951.

Fig. 4-A: Roentgenograms July 29, 1949, five weeks after transplantation. There is evidence of early union at the step cuts. The plaster spica was removed two weeks following surgery and the animal was bearing some weight on the affected extremity on July 16, 1949. Full weight-bearing was noted on August 2, 1949.

Fig. 4-B: Roentgenograms October 19, 1949, four months after transplantation. Good union is present at the step cuts. There is increased bone resorption in the femoral condyles and in the region of the tibial tuberosity.

FIG. 4-C

FIG. 4-D

Fig. 4-C: Roentgenograms October 12, 1950, fifteen and one-half months after transplantation. Changes similar to those seen in avascular necrosis are present, with some narrowing of the joint space.

Fig. 4-D: Roentgenograms July 31, 1951, two years following transplantation. The degenerative changes have not progressed appreciably. Function at the time this roentgenogram was made was good. The animal walked and ran with only a slight limp. Motion of the normal knee: angle of greatest extension, 160 degrees; angle of greatest flexion, 55 degrees. Motion of the transplanted knee: angle of greatest extension, 145 degrees; angle of greatest flexion, 65 degrees.

FIG. 4-E

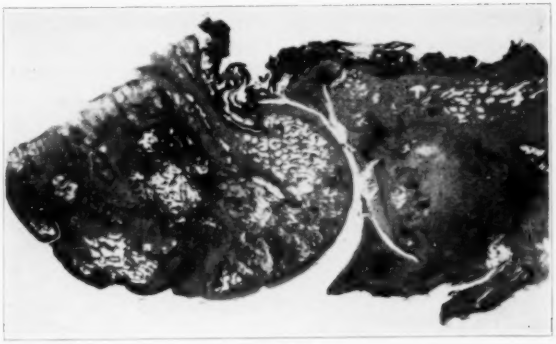

FIG. 4-F

FIG. 4-G

Fig. 4-E: Photograph (× 1.75) of the knee at autopsy July 31, 1951, two years after delayed homogenous transplantation. There is extensive joint disintegration and articular erosion. The menisci are frayed marginally but the cruciate ligaments appear normal.

Fig. 4-F: Longitudinal section (× 2.1) through the lateral femoral condyle and the weight-bearing portion of the tibia. (Hematoxylin and eosin stain.) The marginal half of the meniscus is necrotic and fragmented. The base of the meniscus is replaced by new fibrocartilage. The articular cartilages of both tibia and femur are necrotic, with fragmentation and fibrillary degeneration. There is evidence of repair by fibrocartilage and scar tissue. The spongiosa is necrotic in both femur and tibia, with little evidence of replacement, but the cortical bone for the most part is reorganized. All of the marrow is viable; it is mostly fibrous, but there is fatty marrow in some areas.

Fig. 4-G: Transverse section (× 4.3) through tibial step cut. (Hematoxylin and eosin stain.) Bony union is excellent, but the cortical bone of the graft (lower left) is mostly dead with only slight evidence of endosteal repair. The cortical bone of the host (upper right) is mostly viable with occasional dead tracts. There is advanced but incomplete revascularization of the Haversian systems in the graft, while all of the Haversian canals of the host contain viable vascular tissue.

The animals in the series with delayed homogenous grafts have now been followed for as long as two years. Again, in this series, early clinical results were encouraging, but longer follow-up has revealed certain definite differences from the behavior of the autogenous graft. During the first five to eight months, there is no appreciable difference in function or roentgenographic findings. There has been no detectable difference in wound healing, and the step cut unites promptly, usually within six to eight weeks. Weight-bearing is started after about four to six weeks, and by the end of three months these dogs will run and play in a normal manner. A satisfactory range of motion, apparently without pain, is demonstrable. After five to six months, however, the picture begins to change. The joint continues to function satisfactorily, but the roentgenogram shows increased density in the subchondral area of both the femur and the tibia. There follows a varying degree of degeneration, collapse, and osteo-arthritic changes. Dogs which two to three months after the operation had an excellent gait may begin to limp, and in a few instances, may refuse to bear weight on the affected extremity. Usually, however, satisfactory function persists,

and, surprisingly enough, the dogs continue to bear weight even when roentgenograms show extensive degenerative changes.

At autopsy, the gross findings parallel the roentgenographic impression. During the first few months, the articular surfaces, menisci, and collateral ligaments are well preserved. Scar tissue is possibly a little greater than in the autogenous grafts, but this is difficult to evaluate. Six to eight months postoperatively, however, there is marginal articular erosion, cystic degeneration, and increased fibrous-tissue formation. This process may lead to complete joint disintegration.

Histological study has given us a clue to this difference in behavior. Again, the picture is one of aseptic necrosis, but the timing and the process of repair are different. The marrow is entirely necrotic by the end of seven days and is not completely replaced until after two to three months. The cartilage cells stain poorly a short time after transplantation and superficial necrosis is evident by the end of one month. Rapid destruction of the articular cartilage then occurs with fibrillary degeneration, erosion, osteochondral fractures, and formation of adhesions. Replacement is by pannus which forms scar tissue, and in some places fibrocartilage. The degenerative phase continues through the first eight months with only regional areas of repair. The osteocytes in the cortical bone and spongiosa show pyknotic nuclei by the end of seven days and eventually all bone cells die and disintegrate. Appositional bone formation begins at about three weeks, as in the autogenous grafts, but it progresses very slowly. In some animals, replacement of the necrotic spongiosa is advanced at four months, but in others it remains largely dead even after two years, while in the autogenous series replacement is complete in six to nine months. Cortical replacement is equally indolent. Active reorganization is present at three to four months, but does not progress rapidly or in orderly fashion and is not complete after two years.

In the region of the step cut, union progresses much as it does in the autogenous graft, but at a slower and less uniform rate. In certain instances, union was present at one or more seams by six weeks, but bony union was not present at all junctures until the end of three months. The osteocytes and the contents of the Haversian canals in the graft showed pyknotic nuclei within two days and all cells eventually died. The process of replacement and reorganization is extremely variable and proceeds slowly. Active reorganization is not advanced until after six months and many dead tracts persist even after two years, while in the step cut of the autogenous grafts, complete reorganization is present by six to nine months. Revascularization and osteogenetic activity thus proceed at a strikingly slower pace in the preserved homogenous graft. This would seem to be greater than could be accounted for by the activity of remaining viable cells in the autogenous graft (Figs. 3-A to 4-G and Fig. 5).

These results immediately gave rise to several questions. The degenerative changes in the series with delayed homogenous grafts were almost identical with those we see clinically in aseptic necrosis of the head of the femur but, if removal of the knee joint from its circulation were the only factor involved, one would expect the autogenous grafts to behave similarly. It is apparent that the early degeneration in the delayed homogenous transfers may be due to one of several factors. The method of preservation of the graft may cause death of the cells and changes in the physicochemical structure of the tissue which result in diminution of osteogenetic capacity; or there may be a type-specific protein in the osteoid matrix which creates an antigenic reaction in the host with resultant degeneration of the graft; or there may be a type-specific physicochemical structure of bone which is incompatible with a homogenous host.

It was thought that the outcome in the series with direct homogenous grafts would indicate whether or not the method of preservation was responsible for the degenerative changes noted. Animals in this series have been followed for twenty-four months. Results are closely parallel with those in the delayed homogenous grafts clinically and roentgenographically, and the timing of the repair process is also analogous to that in the series

with delayed homogenous grafts, with replacement occurring at a strikingly slower rate than in the autogenous grafts. In the direct homogenous transfers, the osteocytes and cartilage cells remain viable for a few days longer than in those which had been preserved

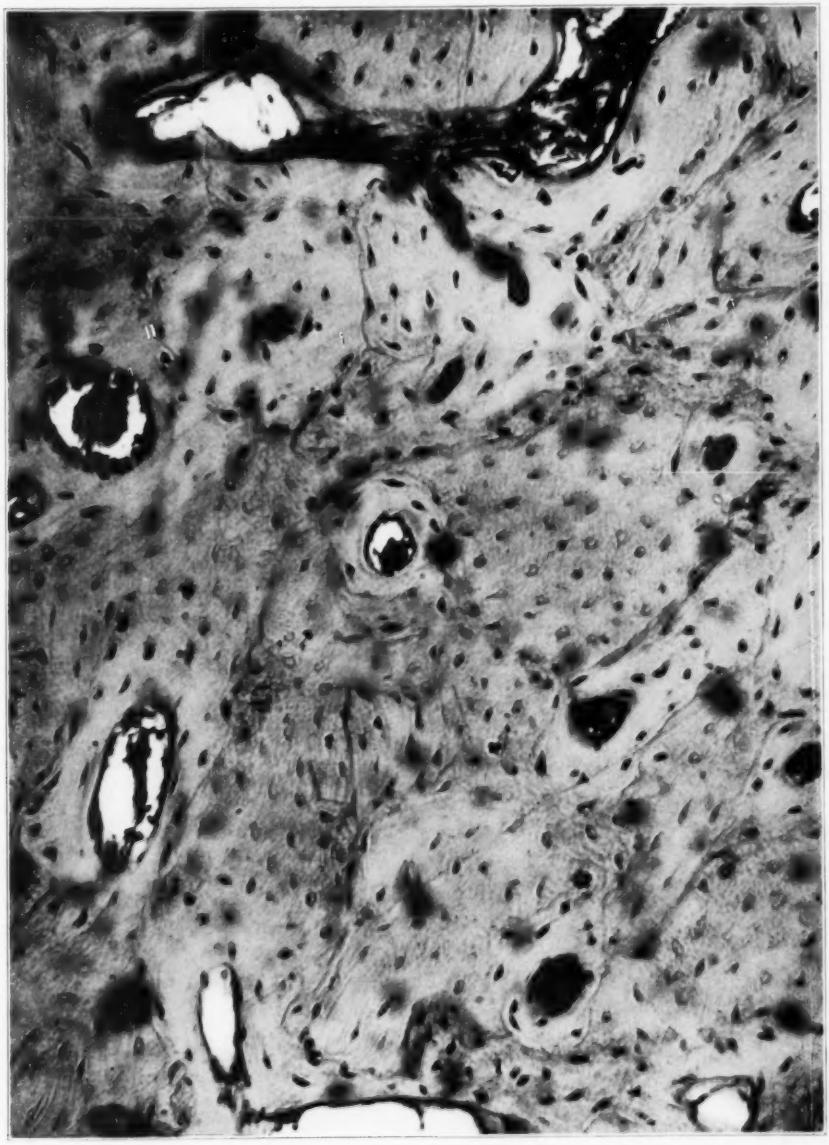

FIG. 5

High-power view (× 160) of the seam between host and graft in the tibial step cut, twelve months after delayed homogenous knee-joint transplantation. (Hematoxylin and eosin stain.) There is excellent bony union although graft bone (lower half) is still almost entirely necrotic. The host bone (upper half) is viable. Revascularization is complete in both host and graft and there is beginning reorganization about the Haversian canals of the graft.

FIG. 6-A

FIG. 6-B

Direct homogenous knee-joint transplantation with two-year follow-up. Operation was on July 26, 1949; the animal was sacrificed on July 31, 1951.

Fig. 6-A: Roentgenograms August 25, 1949, one month after transplantation. There is evidence of early union at the step cuts. The plaster spica was removed two weeks after operation and the animal was bearing full weight on the affected extremity by August 19, 1949.

Fig. 6-B: Roentgenogram January 11, 1950, five and one-half months after transplantation. Mottled areas of diminished density and areas of apparently increased density are now evident.

FIG. 6-C

FIG. 6-D

Fig. 6-C: Roentgenograms July 26, 1950, one year after operation. There has been further increase in the degenerative changes with evidence of compression fractures in both tibia and femur.

Fig. 6-D: Roentgenogram July 31, 1951, two years following transplantation. There is evidence of bone repair, but irregularity of the joint surface and early osteo-arthritic changes are present. The bone appears normal in the step-cut areas. Function at the time this roentgenogram was made was good. There was full weight-bearing with slight limp. Motion of the normal knee: angle of greatest extension, 150 degrees; angle of greatest flexion, 45 degrees. Motion of the transplanted knee: angle of greatest

(*Continued on page 575*)

FIG. 6-E

FIG. 6-F

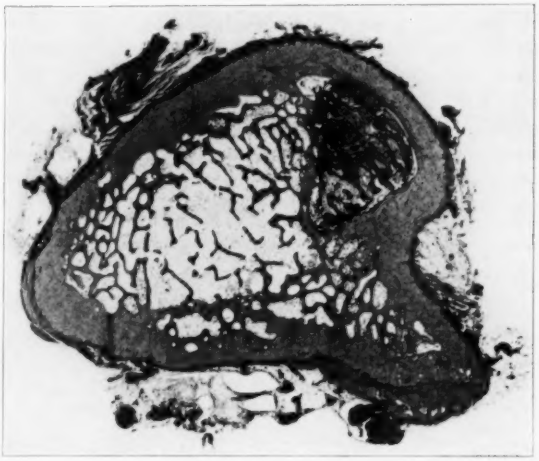

FIG. 6-G

Fig. 6-D (*continued*): extension, 150 degrees; angle of greatest flexion, 65 degrees.

Fig. 6-E: Photograph of the knee joint at autopsy June 31, 1951, two years after direct homogenous transplantation. The menisci and ligaments appeared to be well preserved grossly. There was fibrillary degeneration of the tibial articular surface and rather deep erosions of the femoral articular surface.

Fig. 6-F: Longitudinal section (× 2.1) through the lateral femoral condyle and the weight-bearing portion of the tibia. (Hematoxylin and eosin stain.) The meniscus is necrotic superficially but elsewhere is composed of new fibrocartilage. The articular cartilage is dead throughout with repair by fibrocartilage. There is fibrillary degeneration locally. A large segment including most of the femoral weight-bearing area is partially separated, as in an extensive osteochondritis dissecans. The spongiosa and marrow in this segment are dead, but elsewhere in the femur, the spongiosa is largely replaced by viable bone and the marrow is viable. In the tibia, the spongiosa is dead below the weight-bearing area. Elsewhere, it is viable, and the marrow is viable throughout the tibia.

Fig. 6-G: Transverse section (× 4.3) through the tibial step cut. (Hematoxylin and eosin stain.) The cortical bone and spongiosa is viable throughout. The Haversian canals contain viable tissue. The graft cannot be definitely differentiated from the host.

in a deep-freeze unit. This is particularly noticeable in the region of the step cut where many viable tracts are present up to one month after transfer. Slow extension of necrosis occurs, however, and by three months most of the cells in the step-cut area and all of the cells in the massive portion of the graft are dead. We suspect but have not proved that a few cells in the step cut may remain viable. Again, extreme variability was noted. At the same time, after the operation one animal might show a considerable amount of viable bone with active replacement proceeding, while in another the graft might be almost entirely necrotic (Figs. 6-A to 6-G).

Experiments are now in progress in cooperation with Dr. John Dingle in which immunological techniques are used in an attempt to determine whether or not a type-specific protein exists in bone which will produce antigenic activity in a homogenous host.

CONCLUSIONS

Some of the cells in autogenous whole joints remain viable following transplantation. The bone is rapidly revascularized and the dead bone is replaced with new bone. The deeper layers of cartilage cells remain viable, but some degeneration of the articular surface usually results.

All of the cells in delayed homogenous transplants and most of the cells in direct homogenous whole-joint transplants die. Revascularization and active osteogenesis are slow. The grafts unite and function satisfactorily for six to eight months, but degenerative changes similar to those seen in aseptic necrosis begin between four and six months after transplantation. These changes may progress to complete disintegration of the joint.

Since similar changes occur in direct homogenous transplants as in delayed homogenous transplants, the method of preservation apparently is not the important factor in the early degenerative changes. The factor that produces these degenerative changes, which are so much greater than those in autogenous whole-joint transplants, has not been determined but is probably related to a type-specific physicochemical structure of bone.

The writer has had no experience in using whole-joint transfers clinically, but from the experimental data at hand he believes that one could expect satisfactory results from autogenous transfers, particularly in non-weight-bearing joints, such as the small joints of the hand. Homogenous joint transplants, direct or delayed, heal satisfactorily, unite to the host bone, and are technically feasible. Possibly in non-weight-bearing joints, with good cooperation by the patient, satisfactory clinical results might be obtained. In most instances, however, and particularly in weight-bearing joints, long-term good results are not to be expected at present. It is hoped that further investigative work will reveal methods of accurately matching bone types and thus make such massive homogenous transfers as entire joints acceptable.

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DISCUSSION

Dr. Philip D. Wilson, New York, N. Y.: Like so many other experimental studies undertaken in the past to find the solution of a problem, Dr. Herndon's experimental study of joint transplantation in dogs ends in presenting us with still another riddle. It does, however, give us an answer to what may be expected when we transplant a joint in man. I am sure all of us will commend Dr. Herndon for organizing an excellent series of experiments in a field which previously had been explored only from a clinical standpoint by a few bold surgeons. We should also credit him with great industry and perseverance, because it is

no small thing to perform the laborious and technically difficult operation of joint transplantation on 129 dogs and to overcome the disappointment of the loss of many animals in order to obtain the long-term results in fifty-six survivors. I would like also to congratulate him on his patience in waiting until he had a two-year follow-up period before reporting his study. Just consider how unrealistic his conclusions would have been if he had only followed his experiments for a period of nine months.

The point to be emphasized in these experiments is the difference in behavior of the autogenous and homogenous grafts. For a period of four to six weeks, healing of the grafts followed a similar course in both series, but after that a striking difference became apparent. This difference could not be explained entirely on the basis of survival of cellular vitality in the autogenous grafts, because the survival rate was small in comparison with the bulk of the transplant and the number of cells that died. The reaction of the host tissues to the necrotic part of the graft was different in autogenous grafts and definitely more favorable. In the homogenous grafts, whether fresh or refrigerated, there was no evidence of cellular survival or persistent vitality. Revascularization with absorption and replacement of the dead bone also proceeded at strikingly different rates, and there was a marked difference in the amount of degeneration and collapse of the bony structure. This difference could not be explained on the basis of the method of preservation, because there was little if any difference in the behavior of the fresh or refrigerated homogenous grafts.

These differences in behavior point to the possibility of protein specificity for different animals and of antibody reaction. They cannot be explained on the basis of a difference of blood types, because no difference of this kind has been recognized in dogs; I have been informed that their blood is always compatible. The possibility of protein specificity seems to open an entirely new field for investigation. We have assumed that necrosis of bone could always be explained on the basis of vascular interruption, but these experiments indicate that there may be another and perhaps more important factor. Investigating this factor and how it works may help us to solve many of our clinical problems such as Legg-Perthes disease, osteochondritis dissecans, and osteochondrosis juvenilis.

We may ask why these differences in the behavior of autogenous and homogenous bone transplants have not become evident earlier. I think the answer is that the large joint transplants Dr. Herndon used serve as a magnifying glass in which the process of healing and the histological changes are enlarged. For this reason I find it difficult to draw inferences of clinical value from experiments in which small fragments of bone are implanted in the eyes of rats or guinea pigs, in which grafts are placed by the onlay method on living bones, or in which cancellous grafts are placed in trephine holes in the ilium. My own experience with the two latter experimental methods indicates that every type of bone graft heals readily under such conditions.

I do not think it is necessary to give up all that has been learned about the practical value of a bone bank on the basis of the more favorable behavior of the fresh autogenous transplants in Dr. Herndon's experiments. In most of the cases where we use refrigerated bone, our requirements are not the same as those in Dr. Herndon's experiment. I am willing to admit that an autogenous graft is superior to a refrigerated homogenous graft in bridging a large defect in a bone, and I would prefer to use it in such a case, but for spine fusions and other joint fusions, for filling cystic cavities, and similar defects I would rather use refrigerated bone than one obtained from the patient's own skeleton. We have had success in 85 per cent. of 310 cases of this type; such an experience is too important to ignore.

Finally, I would urge you not to overlook the practical clinical lesson to be learned from the author's study,—namely, that joint transplantation, even of the homogenous type, gives very satisfactory functional results in spite of the degenerative changes that occur. Disintegration of the bony structure is less likely to take place in the non-weight-bearing joints of the upper extremity and transplantation either of a fresh or refrigerated homogenous joint may very well offer a solution in dealing with some of the problems encountered in the treatment of joint deformities or ankylosis, especially in the hand.

I would like to thank Dr. Herndon for giving us the results of his experiments and his conclusions. I hope orthopaedic surgeons in general will study the paper when it is published because it contains much of value. I would also like to ask him to tell us how he proposes to deal with the problem of the difference in the behavior of the homogenous transplants.

DR. CLARENCE H. HEYMAN, CLEVELAND, OHIO: I have been following Dr. Herndon's work with considerable interest, but I am afraid that I can add nothing other than encouragement in the continuation of his efforts. As he has said, he began this investigation with the hope of demonstrating the feasibility of having at hand a supply of preserved joints available for transplantation similar to preserved bone now in use. Although he has failed so far to show that transplantation of large homogenous joints is likely to be successful clinically, his experiments are not without value. They have contributed greatly to our knowledge in transplantation and rehabilitation of homogenous bone, and have given him leads for future investigative work. He has shown that massive autogenous transplants comprising an entire large joint become revascularized and that deprivation of circulation alone is not the chief factor in preventing successful rehabilitation of the transplant. While it is important, of course, to know whether bone cells of transplanted bone remain viable and can reproduce bone, the primary objective of Dr. Herndon's investigation should not be affected by this controversial subject. The important thing from a clinical standpoint is whether a transplanted joint can be rehabilitated, not as a prosthesis, but as an integral part of the host, either through reproductive processes of its own or through reproductive processes of the host.

Dr. Herndon's carefully controlled experiments lead to the conclusion that there is an unknown factor which prevents acceptance of the graft from another of the same species. One is reminded of the fate of homogenous skin grafts which are usually accepted by the host, but which disappear after a few weeks. This failure occurs even when there is similarity of blood groups, but the procedure has been successful in cases of identical twins. It is hoped that Dr. Herndon may find some new blood-grouping or tissue-grouping methods to determine beforehand the compatibility of homogenous transplants. It would seem by the mathematical laws of chance alone, however, that of thirty-eight cases of homogenous transplants there would have been at least a few with successful results equal to those of the autogenous transplants, if compatible grouping alone were to be the answer. I would like to ask Dr. Herndon whether there were any cases in which the homogenous transplants approached the success of the autogenous transplants.

As regards the clinical application of Dr. Herndon's work so far, one should not hesitate to transplant a small joint from one location to another in the same patient in selected cases where this may be desirable.

Dr. Francis McKeever, Los Angeles, California: I wish to present two cases in which a free autogenous transplant of the joint was performed. Because of the unusual nature of the clinical picture, it presented no hazard to the patient and required no boldness in the surgeon.

The first patient was a male, thirty-two years old, who in August of 1944 suffered a shotgun injury in the dorsum of the left hand. When first seen by me in October 1945, thirteen months after his original injury, the patient had a large pedicle graft of the dorsum of the hand and the tissues were in good condition. Roentgenograms at this time revealed a complete absence of the metacarpals of the middle and index fingers. The phalanges of these two fingers with their interphalangeal joints were intact. The middle finger had an intact nerve supply and a normal flexor-tendon apparatus. The index finger was anaesthetic and the flexor-tendon apparatus was non-functioning. On October 11, 1945, a free transplant of the proximal interphalangeal joint of the index finger was done, moving the proximal phalanx, the intact proximal interphalangeal joint, and the middle phalanx of the index finger into the space previously occupied by the metacarpal bone of the middle finger. It was anchored at the carpus by a wire and the distal end of the middle phalanx was inserted into the medullary canal of the proximal phalanx of the middle finger, so that the proximal interphalangeal joint of the index finger was substituted for the lost metacarpophalangeal joint of the middle finger. The soft tissues of the index finger were amputated; healing was by first intention, and there was no soft-tissue reaction. This patient was followed for only six months. But at the end of six months, in May of 1946, he had 30 degrees of useful active motion in the transplanted interphalangeal joint,—that is, about 25 per cent. of the normal motion of this joint.

The second patient was a male, twenty-nine years old, who in August of 1944 suffered a mortar-shell injury on the dorsum of the left hand. The roentgenogram of his original injury shows the extent of the bone damage. The patient was first seen by me in April 1945, seven months after the original injury. Roentgenograms at this time showed a complete absence of the metacarpals of the index and middle fingers. The skin and soft tissues, despite some scarring, were in quite good condition. The middle finger was anaesthetic and the flexor-tendon apparatus of this finger was non-functioning. The index finger had normal innervation and the flexor-tendon apparatus was partially functioning. In May 1945, a free transplant of the proximal interphalangeal joint of the middle finger was done. The proximal phalanx of this finger with the intact capsular ligaments of the proximal interphalangeal joint was spanned into the site of the absent metacarpal of the index finger, the interphalangeal joint being substituted for the lost metacarpophalangeal joint. The end of the middle phalanx was inserted into the medullary canal of the proximal phalanx of the index finger. The distal phalanx of the middle finger was used as a small graft to stabilize the transplant that was based near the carpus. Healing was without untoward event. Roentgenograms in October 1945, six months after the free transplant, showed no evidence of asceptic necrosis in the x-ray of the transplanted phalanges, and the free transplant of the joints still presented a normal x-ray, the joint space being of good width. At this time there was 30 degrees of useful active motion in the transplanted joint.

Dr. J. Albert Key, St. Louis, Missouri: I hope that Dr. Herndon will take time to study the specimens at length. It has been said somewhere that the greatest reward for good work is the ability to do more and better work. These massive grafts offer a tremendous field for study aside from the problems of restoration of circulation to the dead tissue. There are the problems of the restoration or survival of the capsule, the synovial membrane, and the cartilage.

Dr. Charles H. Herndon (closing): In response to Dr. Wilson's question: We have observed that homogenous joint transplantations, direct or delayed, do heal satisfactorily and unite to the host bone; this type of grafting is technically feasible. Possibly in a non-weight-bearing joint and with the patient under good supervision, satisfactory clinical results might be obtained. In most instances, however, and particularly in weight-bearing joints, long-term good results are not to be expected at present. It is hoped that further investigative work will reveal methods of accurately matching bone types and thus make such massive homogenous transfers as entire joints acceptable. Another interesting observation noted in the course of these experiments—and this will answer Dr. Heyman's question—is that some of the homogenous transfers do work, and do follow along the same path as the autogenous transplants; not very many, but some of them definitely have. I believe this is due to the fact that we fortuitously happened to run across a transplant that was compatible in the given host.

CALCIFICATION ADJACENT TO THE PISIFORM BONE*

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Pain in the wrist and weakness of grip are frequent symptoms presented to the orthopaedic surgeon. When there are associated areas of tenderness in the region of the pisiform bone, one must give serious consideration to the clinical syndrome called "calcified pisiform bursitis".

There are numerous articles in the literature on the deposition of calcium in the bursae and tendons about the shoulder. An occasional reference may also be found to calcified bursitis about the elbow, knee, and hip joints. A search through the medical literature of the past thirty years, however, revealed only two articles which deal specifically with the subject of calcification adjacent to the pisiform bone. Cohen, in 1924, reported a case of calcareous deposit at the insertion of the flexor carpi ulnaris tendon which was at first mistaken for a fracture of the pisiform bone. Milch and Green, in 1938, reported eight cases of calcification adjacent to the pisiform bone. More recently, Seidenstein presented fifteen cases of calcific deposits in the wrist and hand; of these, eight were located on the ulnar side of the wrist. Other authors[2, 3, 5, 7] have reported that calcification may occur at the wrist as well as at the shoulder. No author has presented any pathological material obtained from a case of calcification at the wrist joint, because in no case was surgery resorted to in order to effect a cure of the condition.

Anatomically, there is no structure which is designated as the pisiform bursa. There is a bursa of the flexor carpi ulnaris muscle, which is situated immediately beneath the tendon of this muscle near its insertion into the pisiform bone. Actually, from a clinical standpoint, it makes little difference whether the calcification is located within the tendon of the flexor carpi ulnaris or within the bursa of the flexor carpi ulnaris muscle. It therefore seemed best to designate all of these cases of calcification adjacent to the pisiform bone as "calcified pisiform bursitis"; this, of course, is a descriptive term and not a true pathological entity.

Seven patients with calcified pisiform bursitis have been treated by the author during the past five years. Four of these were seen during the past two years and two have been operated upon to cure the condition.

The diagnosis and treatment of calcified pisiform bursitis may best be illustrated by the following case reports:

CASE 1. A housewife, fifty-eight years old, was first seen at the Clinic on December 8, 1949. She complained of pain in her left wrist of three days' duration. There was no history of injury to the wrist. The pain had been gradual in onset and was confined to the anteromedial aspect. There was no radiation of pain into the fingers.

Examination revealed severe localized tenderness over the pisiform bone. The pain in the wrist was exaggerated by complete dorsiflexion and radial deviation of the wrist. There was neither swelling nor redness about the wrist, and there were no sensory changes in the hand. An oblique roentgenogram of the wrist revealed a small area of calcification adjacent to the pisiform bone (Fig. 1-A).

The calcified area was injected with two cubic centimeters of 1 per cent. solution of novocain. No attempt was made to aspirate any of the calcified material, but multiple needle punctures were made in this area. The patient obtained immediate relief from pain following the novocain injection and, when seen in June 1951, reported no further discomfort in her hand or wrist. A roentgenogram of the wrist made in January 1951 revealed no evidence of calcification adjacent to the pisiform bone (Fig. 1-B).

CASE 2. A forty-year-old office worker reported a gradual onset of pain in her left wrist on March 31, 1950. There was no history of injury. The pain was aggravated by any active use of her hand, and she found

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 26, 1951.

FIG. 1-A FIG. 1-B

Fig. 1-A: Case 1. Oblique roentgenogram of wrist shows small area of calcification adjacent to the pisiform bone.

Fig. 1-B: Six months after calcified area was injected with novocain, the calcific deposit had disappeared entirely.

herself considerably handicapped in the performance of her office work because of wrist pain.

Examination revealed a full range of motion in the wrist joint with no evidence of redness or swelling. There was extreme tenderness directly over the pisiform bone. A roentgenogram of the left wrist revealed a small area of calcification adjacent to the pisiform bone (Fig. 2-A).

The tender area was injected with two cubic centimeters of 1 per cent. solution of novocain. Prompt relief was experienced.

One week later the patient returned, complaining of an acute pain in her lower back. A diagnosis of acute lumbar fibromyositis was made. With rest, hot baths, and the application of heat to her back, this condition subsided within the next two days.

Seven weeks later the patient had a second attack of lumbago. There was no history of antecedent illness or injury. The patient had no complaints referable to her left wrist. The pain in the lower back subsided within the next twenty-four hours with physical therapy and rest.

Three days later, on May 29, 1950, the patient was awakened from sleep at three o'clock in the morning by the sudden onset of acute pain in her left wrist. This pain was similar to that she had experienced before the novocain injection two months previously, although the pain was much more severe. Examination revealed an area of redness approximately 2.5 centimeters in diameter in the region of the pisiform bone, with exceptional tenderness in this region. There was also evidence of redness along the anteromedial aspect of the lower third of the left forearm. Any movement of the wrist caused extreme pain. The patient's temperature was normal, and there was no evidence of lymphadenopathy, either at the elbow or in the axilla. A roentgenogram of the left wrist revealed a large area of calcification adjacent to the pisiform bone. This calcified area was considerably larger but less dense than the calcific deposit observed on the original roentgenogram (Fig. 2-B).

Because of the apparently acute infectious nature of the condition, another novocain injection into the calcified area was not deemed advisable. A volar splint was applied to immobilize the wrist, the patient was given an intramuscular injection of 300,000 units of penicillin, and roentgen therapy was instituted. A total of 200 roentgen units was given in the next two days. At this time there was less tenderness and pain in the wrist; one week later the patient had recovered almost completely from all discomfort. A roentgenogram of the wrist made two weeks after the onset of this second attack of calcified pisiform bursitis showed less calcium adjacent to the pisiform bone; however, the calcium was now spread out over a larger area.

One year after the patient recovered from this last attack of bursitis, she had had no further complaints referable to the wrist or hand. A follow-up roentgenogram of the wrist revealed only a few small flecks and a small linear streak of calcium remaining in the region of the pisiform bone and extending along the flexor ulnaris tendon (Fig. 2-C).

CASE 3. A hospital assistant, forty-seven years old, fell on her outstretched right hand December 20, 1949. Following this injury she experienced some pain in her right wrist but did not consider the injury severe enough to warrant medical attention. She first reported to the Orthopaedic Department on February 22, 1950, because of the recent onset of pain and numbness in the area of the ulnar-nerve distribution. She also complained of weakness of grip and pain with active use of the right hand.

On examination, there was observable tenderness in the region of the pisiform bone. There was a complete range of motion in the wrist, with no redness or swelling. There was a positive Tinel sign over the ulnar nerve at the wrist and definite hypaesthesia in the ulnar distribution in the hand. A roentgenogram of the wrist revealed no evidence of old or recent bone injury; there was a small round area of calcification just proximal to the pisiform bone.

The area of the calcification was injected with two cubic centimeters of 1 per cent. solution of novocain. One week later, the patient returned, stating that she had received only temporary relief from the novocain injection. She was sent to the Physical Therapy Department for paraffin baths to the hand, and referred to the Roentgenological Department for the institution of roentgen therapy. She received a total of 1200 roentgen units over a period of two weeks.

Because there was no improvement with conservative treatment, surgical exploration of the tender area at the wrist was performed on March 30, 1950. Immediately beneath the tendon of the flexor carpi ulnaris a distended bursa was evident, containing a loose osteocartilaginous body measuring seven by three

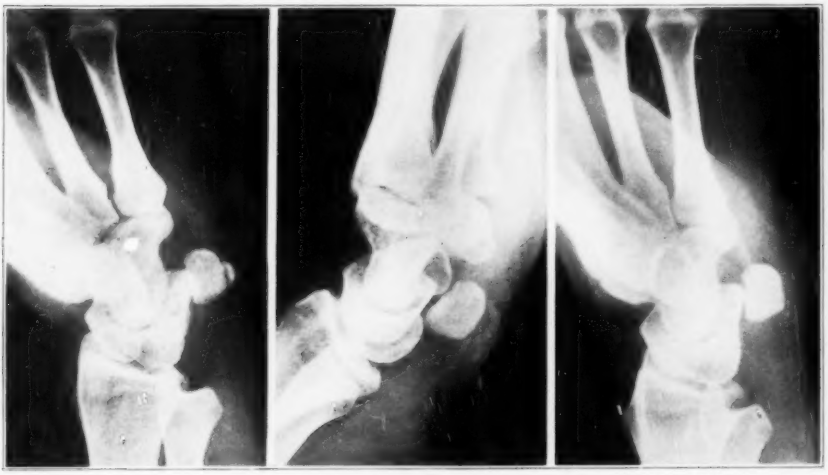

FIG. 2-A FIG. 2-B FIG. 2-C

Fig. 2-A: Case 2. Oblique roentgenogram of wrist shows a small dense area of calcification adjacent to pisiform bone.

Fig. 2-B: Two months later the calcific deposit was less dense but covered a much larger area. The patient was having a second attack of acute pain in the wrist at the time this roentgenogram was made.

Fig. 2-C: One year later there was still evidence of a few streaks of calcification, but the patient had no symptoms referable to her wrist.

by three millimeters. The ulnar nerve was inspected and found to be normal, although in close proximity to the distended bursa. The entire bursa and the loose body were removed.

Numbness and pain in the ulnar distribution in the hand disappeared following the operation, but the patient continued to experience discomfort in the wrist when she used her hand frequently. A forearm cast was applied. When the cast was removed three weeks later, there was no longer any tenderness about the wrist; there was no Tinel sign over the ulnar nerve. When the patient was last seen on December 13, 1950, there was still slight tenderness about the pisiform. She was doing her housework without discomfort. Roentgenograms of the wrist revealed no evidence of abnormality.

CASE 4. A man aged twenty-nine was first seen on November 15, 1950. He stated that two years before he had first noticed some pain in the region of the pisiform bone in the left wrist. This he attributed to pressure from a metal watch band. He discontinued wearing the band, but a burning type of pain persisted along the ulnar side of the wrist. There was no history of any injury to the wrist. Anything which touched the pisiform bone, such as gloves or coat sleeves, aggravated the pain. Active use of the hand also aggravated the pain. He had consulted several physicians and had been told that roentgenograms of the wrist showed nothing abnormal. One physician applied a forearm cast, but there was no improvement following a short period of immobilization.

Examination revealed a full range of motion in the wrist with no evidence of redness or swelling about the joint. There was extreme tenderness over the pisiform bone and some pain upon strong passive flexion of the wrist. An oblique roentgenogram revealed a small area of calcification adjacent to the pisiform bone.

The calcified area was injected with one cubic centimeter of 1 per cent. solution of novocain with immediate relief of pain in the wrist. This injection was repeated on December 8, 1950, as there was no permanent relief from pain following the first injection. Because the relief following the second injection was also temporary, the patient was admitted to the hospital for further treatment. On January 9, 1951, the calcified area in the region of the pisiform bone was explored through a short transverse incision on the volar aspect of the wrist. A calcific deposit measuring approximately three by three by two millimeters was removed from within the tendinous insertion of the flexor carpi ulnaris muscle (Fig. 3-A). Immediately following the operation, the patient was relieved of the former pain in his wrist. He reported no return of any discomfort in his wrist when seen nine months later.

Microscopic examination of the tissue removed at the time of the operation revealed focal areas of degeneration in fibrous tissue and fibrocartilage, with small irregular areas of amorphous calcified material. There were isolated calcified plaques present in the tissue immediately adjoining the tendon and sheath. The largest focus of degeneration and calcification presented a peripheral zone of increased cellularity somewhat resembling a rheumatoid nodule, but without true palisading of the cellular elements (Fig. 3-B).

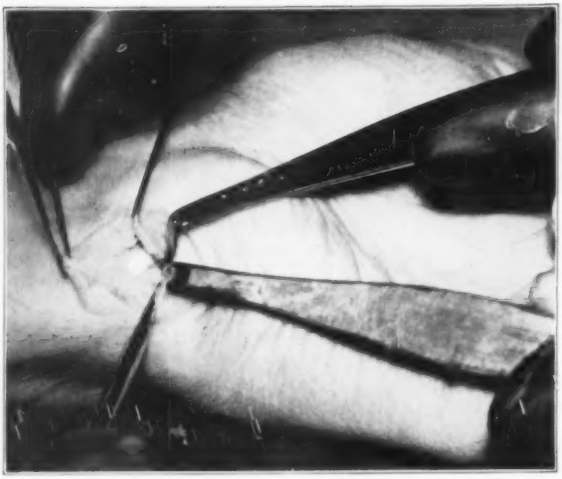

FIG. 3-A

Case 4: The photograph shows surgical exposure of a small area of calcific deposit in the tendon of the flexor carpi ulnaris muscle at its attachment to the pisiform bone.

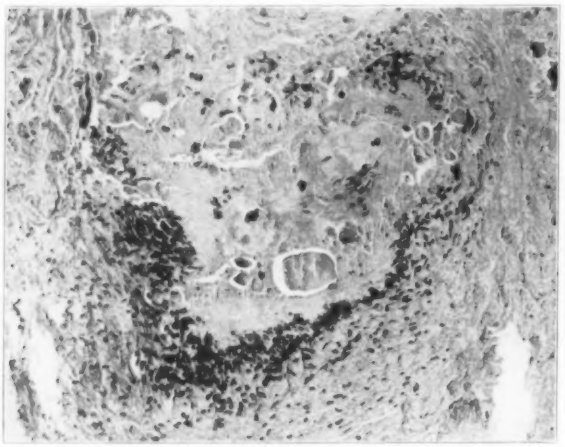

FIG. 3-B

Photomicrograph (× 25) of the same calcific deposit reveals a large area of degeneration with calcified material. The peripheral cellular zone is suggestive of a rheumatoid nodule, but there is no palisading of the cellular elements. There is no evidence of inflammation.

DIAGNOSIS

The condition of calcified pisiform bursitis must be kept in mind whenever a patient complains of pain in the wrist and weakness of grip. The absence of any abnormality observed on the routine anteroposterior and lateral roentgenograms of the wrist does not exclude a calcification in the region of the pisiform bone, because this calcification may usually be demonstrated only with a roentgenogram made obliquely through the wrist with the forearm in mid-supination. This position places the pisiform bone apart from the other carpal bones and demonstrates the soft-tissue calcification which may be present in this region.

When the onset of pain in the wrist is acute, there may be some redness and swelling about the pisiform bone. Usually, however, there is no evidence of any local cellulitis, tenosynovitis, or arthritis of the wrist. A history of injury to the wrist is seldom obtained. In Case 3 there may have been a small "chip" fracture of the ulna or pisiform, which subsequently developed into an osteocartilaginous loose body within the pisiform bursa. This was the only case in which any involvement of the ulnar nerve was noted. With sufficient enlargement of the bursa, however, it is easy to see how the ulnar nerve might be pressed upon and might produce symptoms of pain and hypaesthesia in the ulnar distribution in the hand.

The most constant diagnostic finding is that of localized tenderness over the pisiform bone. This finding, together with roentgenographic evidence of calcification adjacent to the pisiform and relief of the symptom by local infiltration of the calcified area with novocain, make certain the diagnosis of calcified pisiform bursitis.

TREATMENT

The treatment of calcified pisiform bursitis is essentially the same as the treatment

of any calcified bursitis or tendinitis elsewhere in the body. Spontaneous recovery may occur without any treatment. If the symptoms have been of short duration and the calcification has not appeared too dense on roentgenographic examination, infiltration of the tender area with a local anaesthetic or with normal saline solution will frequently serve to puncture the calcific deposit and promote its dissemination and absorption. Relief from pain always occurs immediately with injection of the local anaesthetic and, if the calcification is broken up by the injection, relief from pain is permanent.

Physical therapy, such as diathermy, whirlpool baths, and paraffin baths, may be used in the treatment of calcified pisiform bursitis. This treatment may be helpful in promoting a more rapid absorption of the calcium.

Roentgen therapy should be as effective in cases of calcified pisiform bursitis as it is in the treatment of calcified bursitis or tendinitis in the shoulder. The number of patients treated by this method has not been sufficient to allow conclusions as to the efficacy of treatment. If the calcification is too dense to be disseminated by the infiltration of a local anaesthetic, it is probable that it is also too dense to be affected by roentgen rays. Roentgen therapy should probably be reserved for those patients, infrequently seen, with calcified pisiform bursitis in whom there is evidence of some associated acute cellulitis, such as noted in Case 2 above. It is entirely possible that patients who immediately respond satisfactorily to treatment by local infiltration might react equally well to roentgen therapy, although recovery probably would be prolonged over a period of several days.

Splinting the wrist in neutral position may also hasten recovery by reducing movement in the flexor carpi ulnaris tendon. The initial pain associated with an acute calcified pisiform bursitis will not be significantly reduced by immobilization of the wrist; but the soreness which may follow the successful needling of the calcified area may be reduced by the application of a splint for a day or two.

Surgical treatment should be reserved for those patients who do not respond to more conservative measures. If a definite bursa is found at the time of operation, an attempt should be made to excise it completely. If the calcific deposit is demonstrated within the confines of the flexor carpi ulnaris tendon, only the calcified material itself need be removed.

SUMMARY

Pain over the pisiform bone and weakness of grip are the characteristic symptoms of the clinical syndrome of calcified pisiform bursitis. The calcific deposit is adjacent to the pisiform bone and is located either within the tendon of the flexor carpi ulnaris or within the bursa of the flexor carpi ulnaris muscle. The diagnosis is frequently missed because the calcification is usually demonstrated only on oblique roentgenograms of the wrist. Surgical excision of the calcification should be resorted to only if more conservative treatment fails to give relief. The majority of patients with this condition are promptly cured by local infiltration of the calcified area.

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POSTERIOR DISLOCATION OF THE SHOULDER

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INCIDENCE

Posterior dislocations or subluxations of the shoulder are sufficiently uncommon so that their occasional occurrence creates a diagnostic trap for the unwary surgeon. Twenty-two such lesions have been encountered in 581 shoulder dislocations (an incidence approximating 3.8 per cent.). Six first injuries, diagnosed immediately, responded rapidly and well to simple measures. The remaining sixteen lesions had been diagnosed and treated as other conditions, or had remained untreated for weeks or years prior to recognition. The prognosis became less favorable and the therapeutic difficulties were found to be increased in direct proportion to the length of time these lesions remained undiagnosed.

DIAGNOSIS

Eight lesions resulted from convulsive seizures,—six due to epilepsy and two to electric shocks, of which one was therapeutic and one occupational. Detailed histories revealed a common etiological denominator in the remaining patients,—namely, trauma to the adducted and internally rotated extremity. Examples included a wrestler who fell while held by a "hammer lock", a boxer in the act of punching with an internal rotation twist of the arm, a gymnast "doing a dip" on parallel bars, a pullman porter who was pushing closed an upper berth when the train lurched, a plumber who was pushing on a heavy pipe wrench which slipped, and a football player who fell on his elbow with the forearm caught behind his back.

The signs and symptoms were constant and unequivocal. However, the signs were also unnoticeable until or unless educed. The constant findings included an increased palpable prominence of the coracoid, decreased palpable anterior prominence of the humeral head, increased palpable posterior prominence of the humeral head below the acromion, marked limitation of abduction, and a complete absence of external rotation. Usually neither the increased anterior prominence of the coracoid nor the posterior prominence of the humeral head was visible, except on hindsight, and even to palpation these aberrations were demonstrable with certainty only by comparison with the other shoulder. Displacement of the head of the humerus usually was so small in amount that visible alteration of the long axis of the humerus did not exist. A fixed internal rotation deformity was the rule. Little or no active glenohumeral motion was possible, and attempts at passive manipulation of the joint produced severe pain.

Roentgen diagnosis by films taken in anteroposterior projections was difficult, and at times impossible (Fig. 1-A). The absence of abduction prevented satisfactory roentgenography through the axilla, and transthoracic roentgenograms often were unsatisfactory. However, a roentgenogram taken with the patient erect and facing the cassette obliquely, so that the central roentgen ray corresponded to the long axis of the spine of the scapula, caused no additional damage or discomfort and proved or disproved the diagnosis with certainty (Fig. 1-C).

Eight patients suffered from recurrent posterior subluxations of the humerus. Physical signs of diagnostic value were absent in three of these patients, but detailed interrogation revealed that the recurrent episodes always took place when the arms were flexed, adducted, and internally rotated. One patient could reproduce the subluxations voluntarily, and four others were seen at the time of a recurrent episode, so that evidence of posterior

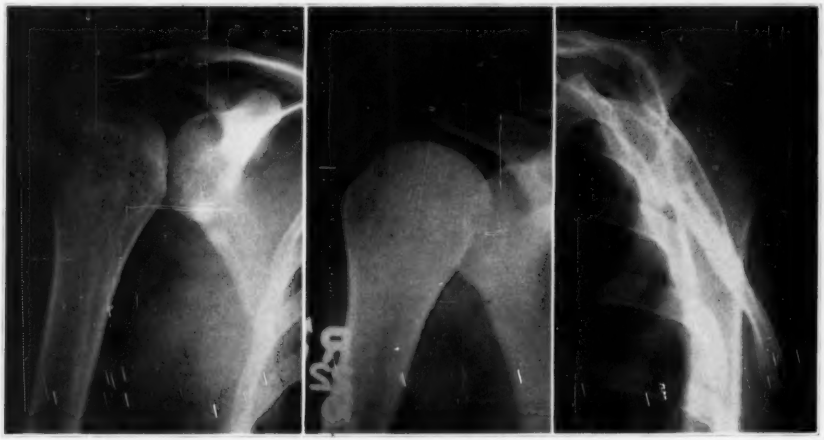

FIG. 1-A FIG. 1-B FIG. 1-C

Posterior dislocation of a few hours' duration, illustrating the diagnostic difficulties encountered in ordinary roentgenograms.
Fig. 1-A: Dislocation before reduction.
Fig. 1-B: Roentgenograms made after reduction.
Fig. 1-C: The tangential roentgenogram, made before reduction, leaves no doubt that a posterior displacement of the head of the humerus is present.

displacement of the humeral head could be demonstrated both clinically and by roentgenogram. In three patients without physical findings, casual histories eliciting only the complaint that the shoulder occasionally went "out of joint" might easily have resulted in diagnoses of recurrent anterior dislocations. Undoubtedly some recurrent posterior subluxations have been diagnosed incorrectly and treated unsuccessfully for this reason. One such instance will be reported here.

TREATMENT

Primary Posterior Dislocation

Six primary lesions were encountered. Five, unaccompanied by demonstrable bone damage, were reduced immediately and easily by (a) anaesthesia sufficient to obliterate pain and muscle spasm, and (b) traction in the axis of the humerus coincident with gentle external rotation and a push against the humeral head from behind. Reduction consistently was accompanied by an unpleasant sound of coarse crepitus, quite unlike the smooth sudden sense of repositioning common to the reduction of an anterior dislocation of the shoulder. Once reduced, no tendency to redislocate occurred under anaesthesia, even when the extremity was adducted, flexed, and internally rotated. The after-care consisted of temporary rest and protection of the extremity by a sling and swathe. Symptoms subsided and function returned in a surprisingly short time—usually a few days to a week. Complete recovery occurred consistently within two to three weeks. Two patients had normal shoulders when lost from follow-up, shortly after active treatment was concluded. Two others had normal shoulders throughout follow-up periods of five and nineteen years. The fifth patient complained of locking episodes about once a month for three years. These always occurred in the act of lifting or pushing with the arm above the head, and reduced spontaneously with a click as the arm was lowered. This patient was followed for ten years, and after the third year his locking episodes (presumably recurrent posterior subluxations) ceased. An almost identical history of personal experiences with this condition is related by one of our surgical colleagues.

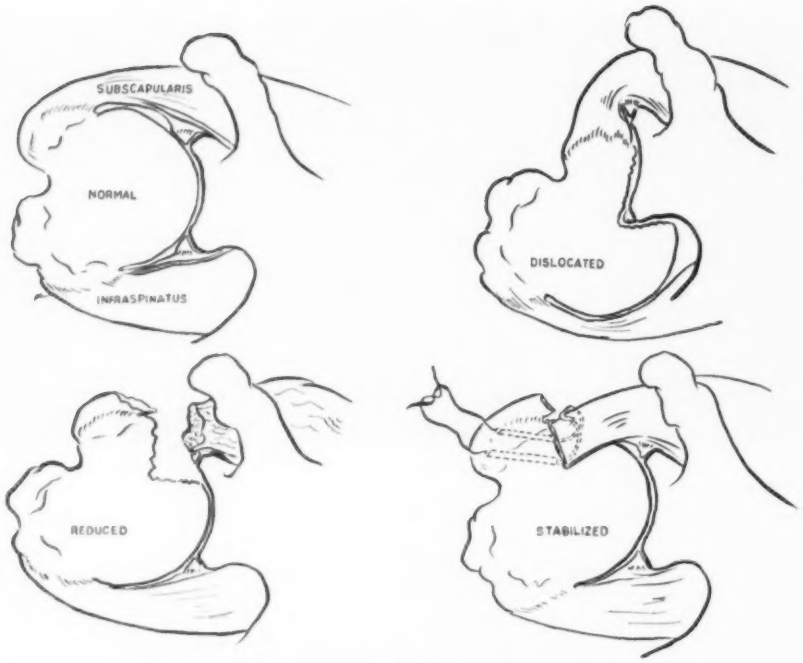

FIG. 2

Upper left: Cross section of the left shoulder viewed from above.
Upper right: The deformity in posterior dislocation with engagement of the posterior glenoid rim in a defect of the anterior aspect of the humeral head.
Lower left: The dislocation has been reduced but instability remains; redislocation occurs with internal rotation, flexion, or adduction. The subscapularis has been divided.
Lower right: Showing technique for stabilization by medial transposition of the subscapularis insertion into the defect.

The remaining primary lesion was complicated by a complex and comminuted fracture involving the intra-articular portion of the humeral head. The humeral head was excised and the remaining components of the shoulder mechanism were reconstructed. A fair functional result (elevation limited to 100 degrees) was obtained. This patient was followed for ten years, during which he was without pain and worked as a porter at Grand Central Terminal.

Old Unreduced Posterior Dislocation

Nine neglected fixed posterior dislocations were encountered: Patient No. 1 had had no treatment during the three months between injury and admission to the hospital. Patient No. 2 had been treated for two months following injury for acute arthritis, "frozen" shoulder, and hysteria, before being referred to this Clinic as a malingerer. Patient No. 3, who was afflicted with acute manic depression, had received continued shock therapy for five weeks after complaining bitterly of severe shoulder pain following the first treatment. However, it is noteworthy that shock therapy was continued only after the orthopaedic and roentgenologic staffs of two hospitals had agreed upon the absence of any organic lesion in the painful shoulder. Patient No. 4 had run the gamut of therapy for "frozen" shoulder, including heavy traction and repeated forceful manipulations under anaesthesia, over a period of three years following injury. Patient No. 5 was admitted to the hospital six weeks after injury, during which repeated unsuccessful

attempts at manipulative mobilization of his stiff and painful shoulder had essentially ruined the head of the humerus. Patient No. 6 had a fracture through the anatomical neck of the humerus with posterior rotation of the head fragment into a dislocated position. The lesion had been immobilized in this position until the fracture healed. Repeated later attempts to correct the displacement by manipulative methods had damaged the humeral head beyond repair. Patient No. 7, an elderly male stenographer, had bilateral unreduced posterior dislocations which, despite many examinations, had remained undiagnosed for thirty-five years. During these years his inability to elevate or externally rotate either arm had required him to work with his typewriter on a stool below and between his knees. Patient No. 8, a young epileptic, had been physically disabled and unable to work for several years because of bilateral lesions which were at first recurrent and finally became fixed in the dislocated position. In short, the most serious potential complication of posterior dislocation appears to be a failure to recognize the lesion.

Patient No. 1 refused operation. Six months after injury only 10 degrees of glenohumeral motion remained, and he was disabled by pain. Three years later most of his pain had subsided, but motion had not increased and was accompanied by marked crepitus. Five years after injury the shoulder had little or no motion, marked crepitus, and considerable atrophy. He had carried on at his regular job as a painter, but was unable to work with the involved extremity. During this period, the posterior half of the glenoid disintegrated progressively, and it appeared that the resultant diminution of pressure upon the humeral head was responsible for the reduction of pain.

Patients Nos. 2, 3, and 8 were operated upon; the humeral head was replaced in the glenoid, and the joint was stabilized against recurrence of the dislocation. Operative findings and procedure were identical in all instances (Fig. 2).

Operative Findings

The subscapularis was stretched around the anterior rim of the glenoid and its tendon proceeded backward across the glenoid cavity to insert into the posteriorly displaced

FIG. 3-A

FIG. 3-B

Fig. 3-A: Roentgenogram of an old, unreduced dislocation. Overlapping of the glenoid and the internally rotated humeral head is apparent, and a defect in the head may be suspected.

Fig. 3-B: Roentgenogram made after repair and restoration of elevation of the arm, illustrating the size and location of the defect in the head of the humerus.

humeral head. The long tendon of the biceps was intact and also proceeded backward to reach the bicipital groove. The glenoid labrum was intact, except for an abraded area in the posterior segment. The glenohumeral ligaments were intact. The posterior portion of the joint capsule was avulsed from both the glenoid labrum and the scapula. The lateral portion of the infraspinatus was elevated from the neck of the scapula by the displaced humeral head. All the intrinsic tendons were intact in continuity.

The dislocated humeral head was depressed and jammed tightly between the posterior margin of the acromion and the posterior rim of the glenoid. Its abnormal position was maintained securely by engagement of the posterior glenoid rim into a deep vertical defect in the anterior aspect of the humeral head. This defect, which approached 1.5 centimeters in depth, was situated just medial to the lesser tuberosity, and was the exact counterpart of the defects in the posterior portion of the humeral head peculiar to anterior recurrent dislocations of the humerus.

Procedure

The shoulder was approached anteriorly through the deltopectoral interval, and was exposed by lateral retraction of the transversely divided anterior deltoid fibers. The joint was entered by transverse division of the subscapularis tendon, as close to its insertion as possible, and retraction of the subscapularis medially. Manipulative reduction proved impossible, even with the subscapularis eliminated and with the joint opened widely. It was necessary to insert a lever between the humeral head and the glenoid and to pry these bones apart. As soon as this leverage disengaged the glenoid rim from the humeral-head defect, reduction occurred spontaneously. However, even a small amount of internal rotation or flexion of the adducted extremity resulted in immediate redislocation, except when the humeral defect was obliterated by an instrument of appropriate bulk. The end of the divided subscapularis tendon was sufficiently large to fill the defect. Therefore, the surfaces of the defect were freshened until vascular bone was exposed, and the subscapularis was reattached to the humerus in the depths of the defect by mattress sutures passed through drill holes in the bone. It was then demonstrated that manipulation of the arm no longer produced recurrence of the dislocation.

Gravity-free pendulum exercises were started after the wound had healed. Gradual resumption of normal use was encouraged, and for several weeks the extremity was protected by a sling and swathe whenever the patient was exposed to external forces beyond his control and while he was sleeping.

Patient No. 2, the pullman porter, (Figs. 3-A and 3-B) was retired six weeks after operation at the age of sixty-five. At that time he was doing light jobs with comfort and had a moderate defect in shoulder motion. Four years later he had no pain and professed full use of the arm as compared to the other side. Mild deltoid atrophy and limitation of 15 degrees in elevation and external rotation was present in the shoulder. Despite the medial transposition of the subscapularis insertion, there was no defect in total internal rotation.

Patient No. 3, the manic depressive, was doing most of her housework six weeks after operation. Three years later, although she refused to come in for re-examination, she denied any significant symptoms or disability of the arm, and stated that motion was almost as good as on the other side. Both shoulders in patient No. 8 were repaired by the same technique; the early result of the first operation was satisfactory, but neither is as yet of sufficient duration for a final evaluation.

Patients Nos. 4, 5, and 6 were operated upon. All had endured repeated forcible manipulations under anaesthesia. The pathological condition in each shoulder was essentially the same as that already described. However, these glenohumeral articulations were damaged beyond any hope of useful function. In patient No. 4 the extent of the damage was obvious. The humeral head was excised and the intrinsic tendons were re-attached to the stump

at about the level of the surgical neck. The postoperative course was smooth, and he was playing golf with only slight discomfort within two months. Insufficient time has elapsed for end-result evaluation. In patient No. 5 the extent of the damage was not appreciated, and the dislocation was reduced and the joint was stabilized by a complex and ill-advised reconstruction of the capsular structures. Maximum rehabilitation was present nine months after operation, at which time the shoulder was stiff, but free from pain. In patient No. 6 the presence of the malunited fracture of the humeral head prevented reduction and stabilization by any means. The humeral head was therefore removed without downward transposition of the intrinsic tendon insertions. Such an economical excision, as has been amply demonstrated in other cases, was a mistake. The patient recovered little or no motion at the glenohumeral joint. Six years later he had a stiff painless shoulder (with total elevation to 90 degrees), but had worked steadily at his regular job as an electrical engineer.

Recurrent Posterior Subluxation

Seven recurrent posterior subluxations have been encountered, in addition to the previously mentioned primary dislocation which partially recurred at intervals for three years after reduction. One patient declined operation and continues to suffer recurrent subluxations which consistently occur when the arm is flexed, adducted, and internally rotated. Another patient had a Nicola procedure done in 1937 for what was then thought to be a recurrent anterior dislocation. At operation a shallow vertical defect in the anterior aspect of the humeral head was noted, but its significance was not appreciated. The result was satisfactory for three years, after which, without further incident, the locking episodes recurred and continued as before operation. Two patients without physical findings were interrogated carefully, and a detailed history was obtained. Despite the absence of physical signs, a presumptive diagnosis of posterior subluxation was made prior to exploration in each instance. The operative findings and procedures were identical. There was a shallow vertical compression defect in the anterior aspect of the humeral head. Flexion, adduction, and internal rotation of the arm reproduced the subluxation under direct vision. In the subluxated position, the posterior glenoid rim engaged the humeral defect which, however, was shallow enough so that a slight motion produced disengagement and reduction of the subluxation. There was no visible damage to the posterior capsule or its scapular attachments. Subscapularis transposition by the technique described above was carried out. One of these patients no longer resides in this country, but has reported annually throughout the last four years that, so far as he can tell, the arm is normal. The second patient is still under treatment. It would have been very easy to treat either patient incorrectly on a diagnosis of a recurrent anterior dislocation of the humerus.

The remaining three patients were seen at the time of a recurrent episode and the diagnosis was established. Two had a manipulative reduction, followed by recurrences, and the other had had previous closed reductions. All had been advised to have operations designed to stabilize recurrent anterior dislocation of the shoulder. Two of these lesions were explored, with findings similar to those mentioned previously. The anterior humeral defects were larger than in the patients with subluxations, which reduced spontaneously, and smaller than those encountered in old unreduced lesions. Both patients have very satisfactory results in all respects at fourteen months and four months, respectively, following their operations.

SUMMARY

Posterior dislocation of the humerus is a diagnostic trap. Clinical and roentgenographic evidence of this lesion is always present, but usually escapes notice unless educed. Recent lesions, recognized and treated at once, respond rapidly and well to simple measures. Recurrent or unreduced lesions require operative treatment. Irreparable damage to

the glenohumeral articulation does not always require arthrodesis. The most common actual and serious potential complication of posterior dislocation of the humerus is the failure to arrive at the correct diagnosis prior to commencing treatment. Some failures of surgical treatment for habitual anterior dislocation of the humeral head result from the fact that the recurrent episodes were in reality posterior subluxations of the humerus.

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Author's Note: In order to avoid leaving the impression that the operative procedure described is a cure for all posterior dislocations of the shoulder, it should be pointed out that, subsequent to submission of this article for publication, two cases were encountered in which it was necessary to use a posterior bone-block procedure in addition to the subscapularis transposition before stability seemed entirely satisfactory.

DISCUSSION

Treatment of Non-Union in Fractures with Infection

(*Continued from page 563*)

Dr. Leo Mayer, New York, N. Y.: In a comparable series of six cases which we had on my Service at the Hospital for Joint Diseases we have been very much helped by the work of our laboratory. The exact determination of the infecting organism and of the sensitivity of that organism to a particular antibiotic has helped us to clear up the infection in many cases. Many of the organisms which were not sensitive to penicillin were sensitive to either streptomycin or aureomycin or to some of the other antibiotics; this is an important feature, I believe, in the control of infection in these cases.

The second point I want to bring out was made many years ago by our great teacher, Dr. Phemister, who emphasized the fact that it is not necessary to use screws in treating a non-union. The less metal we implant, the better.

The third point I want to bring out is this: Although it is a common concept that all the cells of a bone graft die and that the graft simply acts as a framework, research which I conducted more than twenty-five years ago showed that many of the bone cells of cancellous bone remain viable, that many bits of adherent periosteum remain viable, and that probably the viability of these cells accounts for the marked difference between the fate of the cortical graft, which usually dies, and the fate of the cancellous graft, which usually lives.

Dr. Winant (closing): We certainly agree with Dr. Abbott that metal and foreign bodies should be used as little as possible in the treatment of any fracture and that union is not a guarantee against an occasional flare-up in these cases.

As to amputation, I can say that was considered in several of these cases at various times. In one case, it was advised immediately, but the patient refused amputation and we carried out the program described, which terminated very successfully. As for early amputation, I believe that amputation does have a place in some of these very extensively infected comminuted fractures with non-union. However, if particular attention is paid to the various stages in the management of these patients and if time can be allotted to their care and treatment, it is possible to combat infection, to get an intact integument, and to proceed with bone-grafting with a good possibility of union. This series of cases bears that out.

The fact that it is not always necessary to have an intact integument or completely to control an infection has been brought up. As was mentioned in the paper, we attempted to control infection in every instance,

(*Continued on page 679*)

THE USE OF A COMPOSITE PEDICLE GRAFT FOR PSEUDARTHROSIS OF THE TIBIA*

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From The Hospital for Sick Children, Toronto

The purpose of this paper is to record the author's observations in the treatment of three cases of infantile pseudarthrosis of the tibia by means of a method described at the beginning of this century by European surgeons (German [3], Italian [1], and French [2]). The method did not come into general use, and many orthopaedic surgeons of the present time are unaware of their predecessors' efforts. This lack of historical knowledge was shared by the author. After the initial operative procedures had been performed, the literature was searched. It was obvious from the translations of representative articles that the originators were pleased with their results and that they believed a procedure had been introduced which represented an advance in the treatment of this condition. However, diagrams of techniques were not included in the original articles. A record of the author's experiences seemed worth while in order to bring the method to the attention of contemporary orthopaedic surgeons.

The implantation of free bone grafts by a variety of methods often resulted in resorption at the level of the pseudarthrosis. Chip grafts, os novum, inlay grafts, massive onlay grafts for firm splinting, osteoperiosteal grafts, long free fibular grafts from the same leg, two-stage pedicle transplantation of the fibula into the tibia, "by-pass" bone grafts, and others have been used with an assortment of techniques. There appeared to be greater chance of success if the operative therapy were delayed until the patient was at least six or seven years of age. The enormous difficulties experienced in the handling of such cases is sufficiently demonstrated by the great number of methods employed in treatment.

In the three cases to be reported the patients were all under four years of age, and two had been subjected to previous operative procedures before they were seen by the author. In planning the technique to be followed, it was decided to transfer to the area, by a pedicle skin graft, a piece of bone carrying its own blood supply. This composite graft was obtained from the opposite leg. It was hoped that bone retaining for itself an active blood supply at all times would more readily unite to the fragments of the diseased tibia.

The operative work was performed in multiple stages as shown in Figures 1-A, 1-B, and 1-C.

In the first stage, a flap of skin and subcutaneous tissue was raised on the intact leg. Three sides of a rectangle were cut with the short lines above and below the long line on the lateral aspect of the leg. The flap was elevated to the lateral border of the tibia. At this position the fascia over the tibialis anterior was split and the muscle was separated from the lateral side of the bone. A fragment approximately three-fifths of the length and one-half of the thickness of the tibia was separated, with its attachments to the periosteum and to the skin flap kept intact. The incisions were then closed. A reverse type of flap was raised on the diseased leg, the long line of the skin incision being on the posterior surface of the leg, while the flap was elevated from the medial aspect of the leg.

Ten days later, the incisions were opened and the flaps were again elevated. On the intact side the periosteum on the inner side of the tibia was cut and the flap was extended medially. On the diseased leg the flap was extended laterally.

In another ten days the flaps were again raised. On the side of the pseudarthrosis, the tissue between the fragments was resected, together with the bone adjoining the pseudarthrosis; the flaps were reversed. The upper end of the bone graft from the intact leg was

* Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 22, 1951.

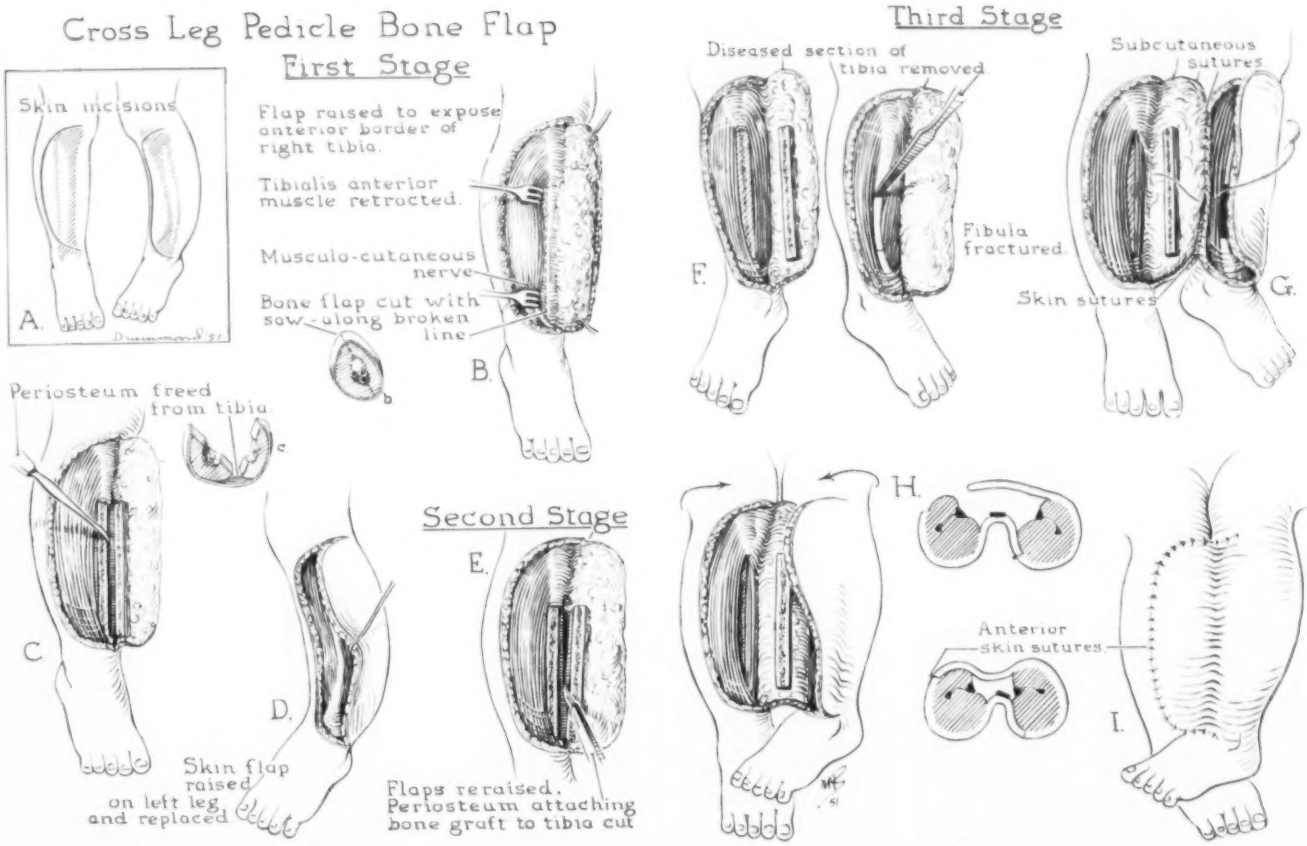
Cross Leg Pedicle Bone Flap
First Stage
Skin incisions
A.
Flap raised to expose anterior border of right tibia.
Tibialis anterior muscle retracted.
Musculo-cutaneous nerve
Bone flap cut with saw along broken line
B.
Periosteum freed from tibia
C
D.
Skin flap raised on left leg and replaced
Second Stage
E.
Flaps reraised. Periosteum attaching bone graft to tibia cut
Third Stage
Diseased section of tibia removed
Fibula fractured
F.
Subcutaneous sutures
Skin sutures
G.
H.
Anterior skin sutures
I.

Fig. 1-A

Fig. 1-B

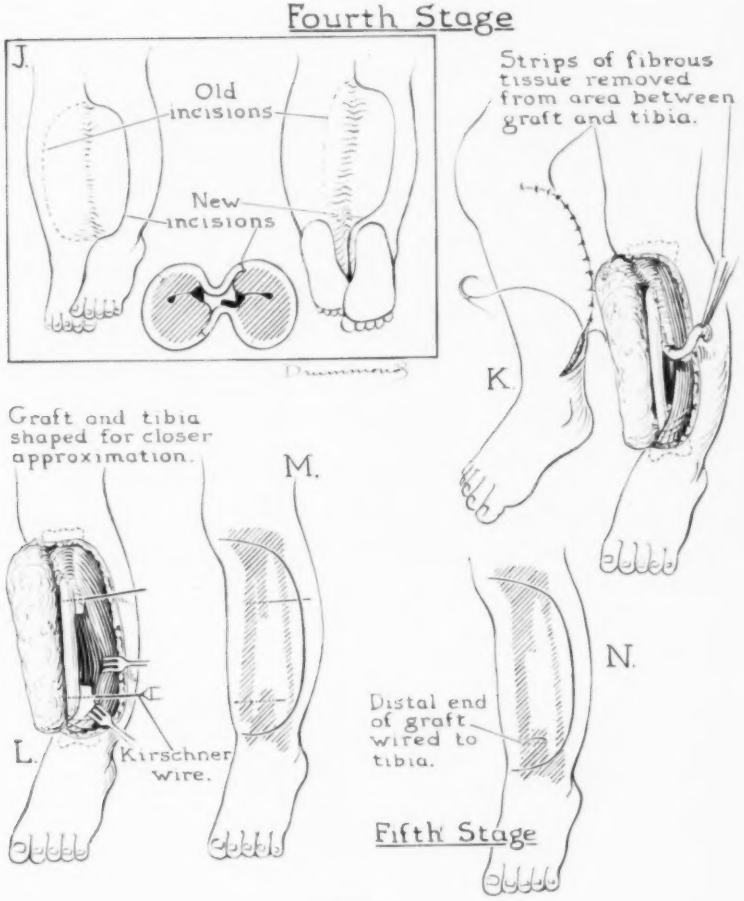

FIG. 1-C

placed as closely as possible to the upper fragment of the diseased tibia, and the legs were sutured together. It was impossible, in any of the three patients, to approximate the bone graft to the lower fragment, due to the obliquity in which it was necessary to hold the legs when the skin flaps were sutured. This inability to place the graft in intimate contact with the diseased tibia was a major defect in the operative technique, as will be demonstrated later. The legs were encased in a plaster splint.

Three weeks later, they were separated; the flaps were transferred, and the wounds were closed. At this stage, it was still impossible to approximate the graft with the lower fragment without endangering the viability of the skin flaps. The union of the bone graft to the upper fragment was rapid, even though the contact was poor in all cases.

After bony consolidation had taken place between the graft and the upper fragment, the lower fragment was placed in contact with the bone graft. In all cases this was accomplished with some difficulty. The space between the fragments had become filled with a dense fibrous tissue similar to that originally removed from the pseudarthrosis. The lower fragment was decalcified and would not hold such metallic apparatus as might ordinarily have been applied to fix it to the upper fragment. The details of the cases are as follows:

CASE 1. A. E. This girl was first seen by the writer at three years and four months of age (Fig. 2-A). The following previous events were noted: At six months of age, a diagnosis had been made of fracture at the juncture of the middle and lower thirds of the left tibia with pseudarthrosis. There was increasing bowing of

FIG. 2-A

FIG. 2-B

Fig. 2-A: A. E. Showing condition at three years and four months of age.
Fig. 2-B: A. E. December 8, 1949. First stage of the procedure. X-rays show length and width of the graft from the intact leg.

FIG. 2-C

FIG. 2-D

Fig. 2-C: A. E. January 4, 1950. Pedicle flaps have been transferred and the legs have been sutured together.
Fig. 2-D: A. E. February 1, 1950. Completion of transfer. Legs have been separated.

FIG. 2-E

FIG. 2-F

Fig. 2-E: A. E. October 1950. Union at both ends of the graft. Weight-bearing without support was allowed.

Fig. 2-F: A. E. June 13, 1951. Solid union after months of weight-bearing without support.

the leg. At fourteen months a fibular graft from the same side was used; this gradually disappeared. At twenty-two months a homogenous bone-bank graft was used with a metal plate fixed by screws for added support. The graft gradually disappeared. At thirty-two months double massive onlay grafts were employed. Chip grafts were used to fill the hiatus between the grafts and the ends of the tibia. This mass was slowly absorbed.

After she had been seen by the author, at the age of three years and four months, the series of operations as described were undertaken over a period of two months (Figs. 2-B, 2-C, and 2-D). Union of the graft to the upper fragment was rapid. Following this, the approximation of the graft to the lower fragment was undertaken.

The child was discharged from the Hospital in plaster splints between operations. Ten months after the original procedure she was allowed to begin to walk in a walking plaster. Union at the lower fragment became solid (Figs. 2-E and 2-F).

CASE 2. B. L. The leg deformity in this girl was noted shortly after birth. She was twenty-two months of age when first seen by the author. The leg was then splinted.

The series of operations described, with the exception of the last stage, were completed over a period of about two months (Figs. 3-A, 3-B, and 3-C). At this time the upper fragment was uniting strongly to the bone graft. The approximation of the lower fragment to the graft was difficult (Fig. 3-E), and firm internal metallic fixation was impossible because of the decalcification of the bone. Massive onlay grafts between the bone graft above and the lower fragment below might have solved the problem at this stage. However, it was decided to attempt to determine whether union could be obtained without the use of additional grafts. Accordingly, when union was not obtained (Fig. 3-F), the child was sent home for a number of months with all retentive splinting removed. The fragments were then approximated firmly with a wire loop. Union at the lower end was obtained (Fig. 3-G), and the child was allowed to walk. Refracture (Fig. 3-H) occurred at the lower end of the tibia on unsupported weight-bearing. The leg had some bowing, and was about one-half inch short.

CASE 3. M. Q. This girl was brought to the surgical clinic at six months of age with marked anterolateral bowing at the juncture of the middle and lower thirds of the leg (Fig. 4-A). There was diminution in the caliber of the tibia at this level. A fracture was reported a few weeks later. This was obvious when the patient was seen by the writer, at the age of one and one-half years (Fig. 4-B).

The series of operations previously described were performed (Figs. 4-C and 4-D). They were technically difficult, due to the short fat limbs of the child. The upper end of the living bone graft was approximated

without difficulty to the upper fragment of the affected tibia, after excision of a large section of the pseudarthrosis. As it was impossible to approximate the lower end without endangering the circulation of the skin flap, this was delayed until union was solid at the upper end. Then the fibula was fractured, and the lower

FIG. 3-A

FIG. 3-B

Fig. 3-A: B. L. May 5, 1949. Showing size of graft taken from intact leg.
Fig. 3-B: B. L. June 6, 1949. Pedicle flaps have been transferred and legs have been sutured together.

FIG. 3-C

FIG. 3-D

Fig. 3-C: B. L. July 4, 1949. Completion of transfer. Legs have been separated.
Fig. 3-D: B. L. Solid union above and obvious non-union below.

fragment was pushed into contact with the bone graft. The fixation was unsatisfactory. As an obvious non-union with deformity was developing and the lower fragment was decalcified, all splinting was removed

FIG. 3-E

FIG. 3-F

Fig. 3-E: B. L. November 19, 1949. Lower fragment placed in contact with the lower end of the graft.
Fig. 3-F: B. L. Obvious non-union at the lower end. Bones had become decalcified. Patient was sent home without splinting and was not allowed weight-bearing.

FIG. 3-G

FIG. 3-H

Fig. 3-G: B. L. December 14, 1950. Union after re-apposition at lower end.
Fig. 3-H: B. L. March 7, 1951. Recent refracture on unsupported weight-bearing.

(Fig. 4-E). Some time later, in March 1951, free bone grafts of the onlay type were used with cancellous bone packed in the hiatus between these grafts and the ends of the tibia. On December 5, 1951, x-rays revealed that the bone grafts were consolidating. Union was presumed to be taking place (Fig. 4-F).*

FIG. 4-A
M. Q. Age six months. Showing bowing of the tibia.

FIG. 4-B
M. Q. Age eighteen months.

FIG. 4-C

FIG. 4-D

Fig. 4-C: M. Q. January 5, 1950. Pedicle flaps have been transferred. Legs have been sutured together.
Fig. 4-D: M. Q. February 3, 1950. Completion of the transfer. Legs have been separated. Bone graft is in poor contact at both ends, since skin flap was not mobilized because of danger to the blood supply.

*This patient now has solid union and has been allowed up with unsupported weight-bearing.

FIG. 4-E

FIG. 4-F

Fig. 4-E: M. Q. Union at the upper end was rapid; non-union at the lower end.
Fig. 4-F: M. Q. December 5, 1951. The bone grafts were consolidating.

COMMENT

The European surgeons who first used composite grafts for this condition raised a very thin sliver of bone with the periosteum, which in turn was left attached to the skin flap. The transfer was performed directly, without such previous preparatory stages as have been outlined. A large section of the tibia with the pseudarthrosis was not removed. Thus, there was no need to cut the grafts either as long, as wide, or as thick as were those used in the three cases reported here. Definite advantages accrue from this earlier method, for it is possible to approximate the smaller and more flexible graft more easily to the affected tibia. This was the main difficulty in the method outlined. In retrospect, it would appear easier to transfer a small section of ulna by way of the forearm as a direct shift. Immediate approximation of the graft, after correction of the deformity, would then be possible. To support the unusual position necessary for such a direct transfer should not be too difficult.

SUMMARY

Three children with tibial pseudarthrosis were treated with cutaneous-bone pedicle grafts in order to determine whether such a method would constitute a successful form of therapy for this condition at this age level.

Although the principle involved appeared sound, the operation as described is not recommended. Union between the graft and the upper tibial fragment occurred rapidly. Technical difficulties may have been the cause of the delay in fusion at the lower end. It may be possible to overcome these difficulties by the use of a bone pedicle graft from another area, such as the ulna. Accurate approximation of the graft to the tibial fragments at the time of the initial transfer might then be possible. This would appear advantageous.

These results have been placed on record, so that the obvious errors may be avoided

by others who may carry forward the technique. It was first used without previous knowledge that a procedure based on the same principle had been employed by European orthopaedic surgeons at the turn of the century.

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DISCUSSION

Dr. Arthur B. LeMesurier, Toronto, Ontario, Canada: Dr. Farmer has presented a method of treating cases of congenital pseudarthrosis by transplanting a piece of living bone. In some ways this looks better than any form of free bone-grafting. Whether the cause of all these cases of pseudarthrosis is neurofibromatosis or not, I think it is generally believed that there is some slow-acting process of destruction going on about the fracture and that the first step of any treatment should be a rather extensive excision of bone from both fragments. This leaves in the tibia a large gap which has to be bridged. It is in this that the living transplant has the advantage over a free graft.

The pedicle transplant is different from the free graft mainly in that its circulation is more or less intact and practically all of its cells are living. It behaves throughout like living bone and does not have to wait until it is invaded and replaced by living tissue growing into it. Dr. Farmer has shown that this transplant can do its part in producing union with the fragments of the tibia and that, from the start, it can lay down new bone and can rapidly become thicker and stronger. Since the whole transplant is living throughout the entire procedure, there is practically no limit to the size of the gap in the bone which can be bridged, as there is with a free graft. There are many other conditions besides congenital pseudarthrosis in which a gap is left in the bone that may be considered too large to bridge with any form of free graft; in these cases this same method might be used. In addition to its ability to bridge a gap of any size, the living piece of transplanted bone has a certain amount of resistance to infection. In cases in which there is a possibility of lighting up an old infection, this method may well have its advantages.

Dr. Farmer has suggested that in addition to the tibia some other bone, such as the ulna, might be used to provide the pedicle graft. This would make it possible to bridge a gap in almost any bone in the body. I think that Dr. Farmer is to be congratulated on the rather wide field that he has opened. The chances are that much more can be done with a pedicle bone graft now than could have been done by Codivilla forty-five years ago, when much less was known about the use of these flaps.

This bridging of wide gaps in bone is really an orthopaedic problem, but to do it in this way requires a fair knowledge of plastic surgery. The modern idea of calling in a plastic surgeon to do the work on soft tissues in these operations, while the orthopaedic surgeon touches nothing but the bone, seems to me to be unreasonable. This is a case where the surgeon would be better able to handle a problem which was mainly but not entirely orthopaedic—and there are a good many of these—if his training and work had not been limited strictly to orthopaedic surgery and had included some of the other closely allied branches of surgery.

Dr. John R. Moore, Philadelphia, Pennsylvania: Dr. Farmer has presented a very interesting procedure. Its usefulness has been demonstrated in one of the three cases which he has presented. There are difficulties to be overcome,—namely, the difficulty in obtaining contact, the difficulty of immobilization, and the possible risk of infection at the donor site as well as at the site of the pseudarthrosis. However, the pedicle bone graft, whether the graft be included in the skin flap or in the muscle flap, is by far the best graft available today. Dr. Hibbs in his spine-fusion operations and his operations for arthrodesis of the hip has emphasized the value of the pedicle graft. I sincerely hope that Dr. Farmer will continue with his research in this problem and that he will present additional cases at some future date.

Dr. A. W. Farmer (closing): I wish to thank the discussers for their kind words. Possibly a point which was made in the paper missed your attention. The age level of the patients was emphasized; and this appears to be very important. Operative procedures which might be performed with success in patients beyond seven to ten years of age are unsatisfactory at a lower age level. McFarland, in his recent article, stated that one of his cases, now approximately fourteen years from the time of operation, represented the youngest patient whose medical history had been recorded in whom union had been obtained. The first patient shown here is still younger. I wanted to emphasize that it was at this low age level, where success is practically unknown, that we were trying to deal with these cases of pseudarthrosis. Concerning the question of neurofibromatosis which Dr. LeMesurier brought up, two of these patients showed *café au lait* marks on their bodies. The third one did not. The pathologists were quite willing to give us a diagnosis of neurofibromatosis from the appearance of the pathological section but, on the other hand, they were not certain that the tissue in question arose from nerve. The sections showed a picture similar to that concerning which Green and Rudo wrote.

RHEUMATOID GRANULOMATOUS NODULES AS DESTRUCTIVE LESIONS OF VERTEBRAE

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That granulomatous nodules occur in the subcutaneous tissues of patients with rheumatoid arthritis has been well known since the time of Pitt. The clinical characteristics and histological structure of these nodules have been well delineated in a number of excellent studies[3,6–9,11]. In recent years, investigators have also found these lesions in the heart[1,2,4,5,10,13], scalp and abdominal wall[13], larynx[13], pleurae[10,13], and peritoneum[10,13]. Granulomatous nodules have been described in the subchondral regions of the bones of the extremities when the adjacent joint is involved. These presumably indicate an invasion of the bone by the inflammatory process which involves the joints and are, of course, characteristic of rheumatoid arthritis. In one case, which we are presenting, the granulomatous nodules were shown to occur in the body of the vertebrae where there is no synovial membrane and where, to our knowledge, the presence of such lesions has not been described previously.

We are also presenting three other cases of rheumatoid spondylitis and destructive lesions in vertebrae; in these three cases tissue was not available for histological examination but, because of the clinical findings and course, the lesions were presumed to be caused by similar rheumatoid granulomatous nodules.

The findings presented in this report suggest that the rheumatoid granulomatous nodule must be considered in the already difficult task of clinical and roentgenographic differential diagnosis of destructive lesions of bone.

REPORT OF CASES

CASE 1. A man, aged fifty-six years, registered at the Mayo Clinic on September 6, 1950. The patient had been well until June 1947, when without apparent cause the tarsal region of the left foot became painful, swollen, warm, and red. Late in 1948 the ankles and, subsequently over a period of two years, the knees, wrists, elbows, shoulders, and temporomandibular joints also became chronically involved. The symptoms became worse in July 1950. Since then he had experienced extreme weakness, tiredness, and anorexia; and he had lost twenty-five pounds (11.3 kilograms). During the month before admission, pain and stiffness had been present throughout the back. Because of the severity of his symptoms, the patient had been unable to work since July 1950, and, during the month before admission, he had been confined to bed. Physical therapy and salicylates had given only transitory relief of symptoms.

A review of systems at the Clinic revealed the fact that he had had precordial pain occasionally on exertion for the past two years.

On physical examination, moderate to marked tenderness, moderate limitation of motion, and slight swelling of the elbows, wrists, metacarpophalangeal joints, proximal and distal interphalangeal joints, knees, ankles, and metatarsophalangeal joints were noted. A firm subcutaneous rheumatoid nodule was present in the left subolecranon region. Dorsal kyphosis and flattening of the lumbar curve with a slight degree of paravertebral muscle spasm were noted. Flexion and extension of the spinal column were moderately limited. The liver extended two to three centimeters below the costal margin and the spleen was found to be enlarged on palpation. The prostate was slightly enlarged and smooth. The remainder of the general physical examination gave essentially normal results.

The first urinalysis revealed no abnormalities, but the second indicated albuminuria, Grade 2, and Bence-Jones proteinuria. The estimation of hemoglobin was 11.6 grams. The erythrocyte count was 3,870,000 per cubic millimeter of blood, and the leukocyte count was 13,100. Examination of a stained blood smear revealed

FIG. 1-A

FIG. 1-B

Case 1. Portion of spinal column.

Fig. 1-A: Lateral roentgenogram showed destruction with anterior wedging of the body of the twelfth thoracic vertebra.

Fig. 1-B: Bisected spinal column at necropsy. Destruction of the twelfth thoracic vertebra and a nodule in the third lumbar vertebra are apparent.

nothing of diagnostic importance. The determination of blood urea was 26 milligrams per 100 cubic centimeters on September 7 and 72 milligrams on September 25. Direct reacting bilirubin was not found on two examinations. The values for indirect reacting bilirubin were 0.9 milligram and 0.7 milligram per 100 cubic centimeters of serum. The level of serum protein was 6.6 grams on September 12 and 5.9 grams on September 19. The values for albumin were 3.7 grams and 3 grams and for globulin 2.9 grams on these same dates. The value for alkaline phosphatase in the serum was 3.5 King-Armstrong units and for acid phosphatase 1.4 King-Armstrong units per 100 cubic centimeters of serum. The sulfobromophthalein tests of liver function revealed 12 per cent. (Grade 2) retention of dye on September 9 and 6 per cent. (Grade 1) retention of dye on September 12. Results of the cephalin-cholesterol flocculation test were negative. The tuberculin skin test gave positive results with 0.0001 milligram of purified protein derivative.

Roentgenographic examination of both wrists, hands, feet, and knees revealed generalized osteoporosis. There was evidence also of effusion into both knees and of a healed Freiberg's infraction of the distal head of the second metatarsal bone on the right. Roentgenographic examination of the spinal column revealed hypertrophic changes and slight lumbar scoliosis. There was pathological wedging of the body of the twelfth thoracic vertebra with destructive and proliferative changes about its anterior portion (Fig. 1-A).

A clinical diagnosis of severe rheumatoid arthritis was made, and the possibility of a mild latent cirrhosis of the liver was considered. The roentgenographic finding of a destructive lesion in the twelfth thoracic vertebra brought up consideration of a metastatic neoplasm, multiple myeloma, or infectious granuloma; but all efforts to confirm such diagnoses were inconclusive. Sternal aspiration on September 16 revealed a few clumps of plasma cells but not enough to justify a diagnosis of multiple myeloma. On September 22, a needle aspiration of the twelfth thoracic vertebra was performed under roentgenographic control, but the tissue removed was not suitable for a histological diagnosis.

Course

After the examination had been completed, a program of treatment for the rheumatoid arthritis was started. This consisted in daily physical and occupational therapy; aspirin, 10 grains (0.65 gram) four times a day; a high-carbohydrate, high-protein diet with multivitamin supplements; and limitation of activities to prevent overuse of inflamed joints and to ensure adequate rest. Many of the patient's joints began to show improvement in range of motion, but subjective stiffness, soreness, and swelling persisted. Weakness and anorexia continued.

Shortly after the patient had eaten supper on September 24, 1950, a mild substernal pain developed which at first was accentuated by deep respirations. The pain rapidly increased in severity, and the patient became dyspnoeic. The heart rate was 120 beats per minute, cardiac rhythm was regular, and no abnormal cardiac or pulmonary sounds could be heard. Blood pressure had fallen to 80 systolic and 60 diastolic.

An acute myocardial infarction was suspected. The patient was given morphine, barbiturates, papaverine, oxygen by mask, and dicumarol. Within four hours after the onset of the attack, improvement was apparent. By the next morning, he was much better; however, tachycardia and poor heart tones persisted. On September 26 an exacerbation of the substernal pain occurred. Bilateral basal râles, increased dyspnoea, orthopnoea, hemoptysis, and pretibial oedema developed. Increased venous pressure became evident in veins of the neck and arms. Digitalization was accomplished and a mercurial diuretic, aminophylline, and penicillin were given. However, the patient's condition became progressively worse, and he died September 28, 1950.

Necropsy

Each pleural cavity contained about 1,000 cubic centimeters of turbid yellow fluid. The pericardial cavity contained 100 cubic centimeters of turbid amber fluid, and its surfaces were covered by a shaggy fibrinous exudate. The heart weighed 545 grams. The right coronary artery was partially obstructed two centimeters from its origin by an atheromatous plaque about one centimeter in length. The remainder of the right coronary artery and the entire left coronary artery revealed only a mild degree of atherosclerosis. The left posterior papillary muscle and the subjacent endomyocardium were white, shrunken, and firm. The aorta was the seat of severe atherosclerosis.

The trachea and bronchi contained copious amounts of watery, clear mucoid secretion. The right lung weighed 1,500 grams and the left lung 610 grams. Firm strands of fibrous adhesions attached the apices to the parietal pleurae superiorly, laterally, and posteriorly. Only the superior portions of both upper lobes were aerated. The remainder of the pulmonary parenchyma was heavy and solid with oedema. There was an apparently healed primary tuberculous complex in the left upper lobe and hilar lymph node. The latter was calcified. The sectioned surfaces of all lobes were extremely moist, firm, rubbery, and dark purplish. In the left upper lobe of the lung, there was an area, 1 by 1.5 centimeters, of firmer consistency than the surrounding parenchyma.

The spleen weighed 295 grams. Fibrous adhesions were scattered over the surface and there was hyaline thickening over the diaphragmatic portion. The parenchyma was soft and the follicular markings were indistinct. The liver weighed 2,085 grams. The sectioned surfaces were light brown with normal lobular markings. There were many tiny superficial erosions in the mucosa of the stomach. One centimeter distal to the pylorus was a recently developed shallow ulcer, 0.8 centimeter in diameter. The kidneys each weighed 200 grams. Residual foetal lobulations were present. The cortex measured 0.9 centimeter and the medulla 2.3 centimeters in thickness. The corticomedullary markings were distinct.

The twelfth thoracic vertebra had become a grayish amorphous mass with compression of the body (Fig. 1-B). The third lumbar vertebra was the site of a grayish nodule contiguous with the disc on its upper surface. Examination of the spinal cord and brain revealed no abnormalities.

Histological Examination

In sections of the mitral valve the numbers of lymphocytes and histiocytes at the base of the leaflet were increased slightly. In the myocardium adjacent to the root of the leaflet there was a large collection of histiocytes, fibroblasts, and Anitschkow's myocytes (myocardial reticulocytes) in the interstitial connective tissue (Fig. 1-C). These cells were in palisades about fragments of necrotic tissue, presumably collagen, and degenerating cellular tissue. Many of the large palisaded cells had large atypical nuclei and some of the latter revealed evidence of pyknosis and karyorrhexis. The cytoplasm of these cells was pale, acidophilic, and extended into long processes. Surrounding the large palisaded cells were numerous lymphocytes and fibroblasts. Muscle fibers in the vicinity of the granuloma appeared atrophied and necrotic. In another section taken from the apex of the left ventricle there was a larger granulomatous nodule which appeared to be the result of fusion of several smaller nodules, similar in appearance to that already described (Fig. 1-D). A few polymorphonuclear cells were observed among the other cellular elements. Some of the nuclei of the muscle fibers appeared hypertrophied, whereas other fibers revealed evidence of atrophy and necrosis. There were increased numbers of lymphocytes and phagocytes between the muscle fibers for some distance from the nodule. In other sections small collections of lymphocytes and fibroblasts usually associated with vessels were frequently observed. In sections from the posterior portions of the left ventricle and interventricular septum,

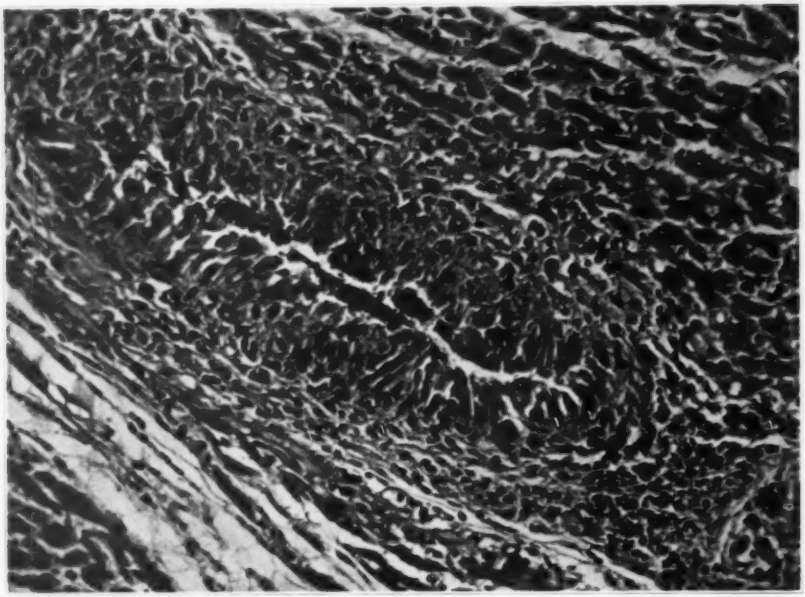

FIG. 1-C

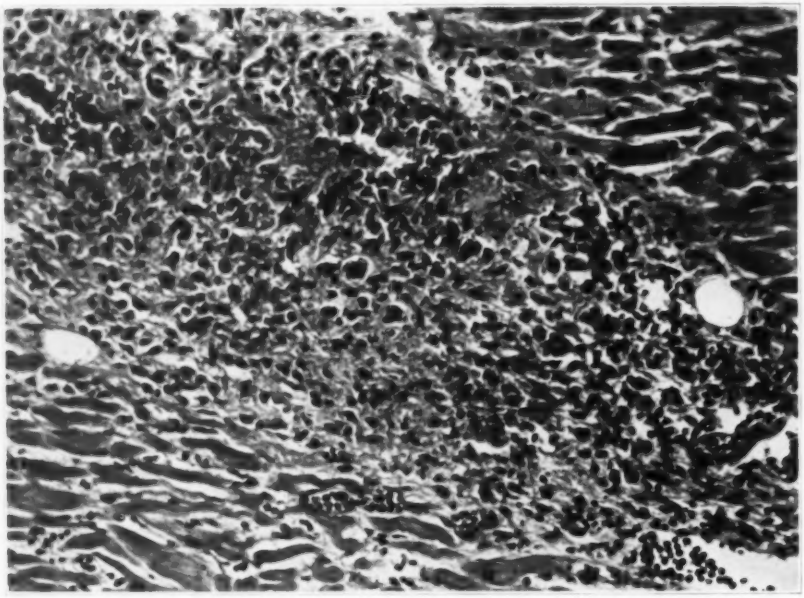

FIG. 1-D

Case 1. Myocardium.

Fig. 1-C: Granulomatous lesion at base of the left ventricle (× 245). Palisading of large cells about a necrotic central region may be noted (hematoxylin and eosin stain).

Fig. 1-D: Granulomatous lesion from apex of left ventricle (× 245). Probably several smaller granulomata have fused (hematoxylin and eosin stain).

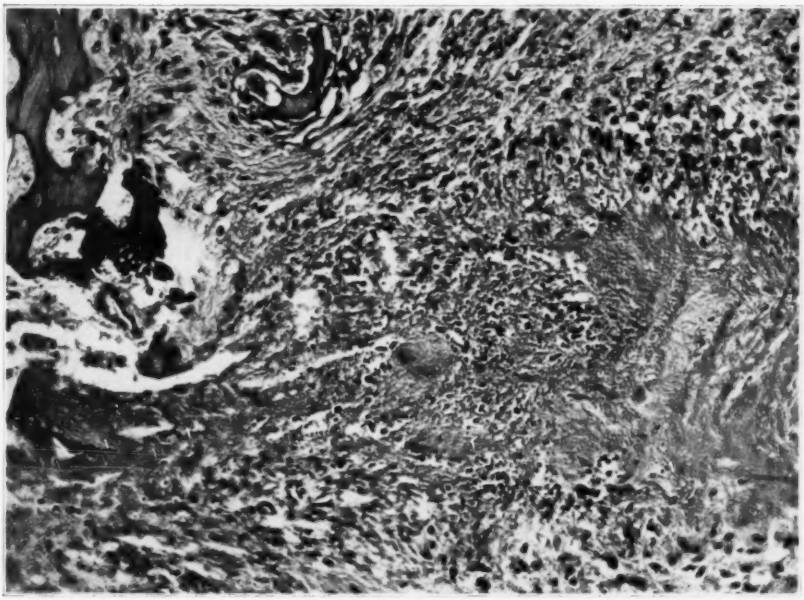

FIG. 1-E

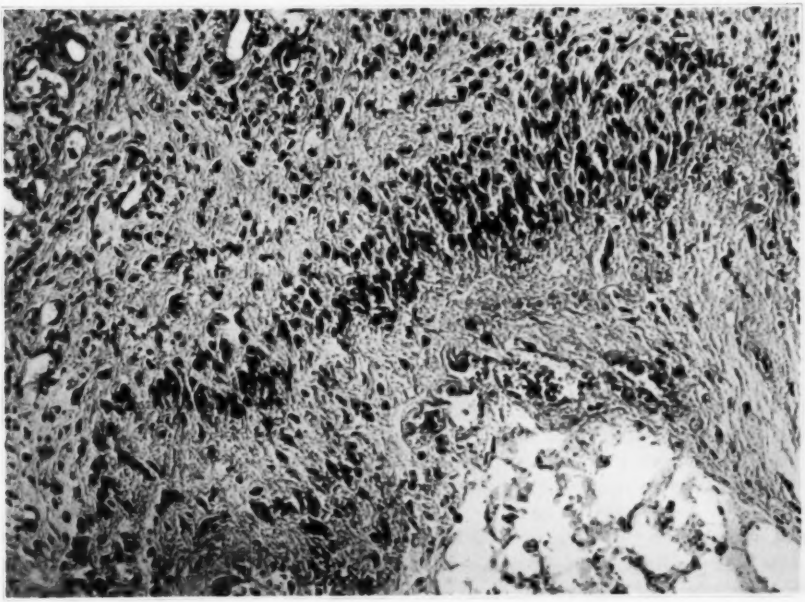

FIG. 1-F

Case 1. Vertebra.

Fig. 1-E: Granulomatous nodule (× 207) in third lumbar vertebra. Palisading of fibroblasts around a central necrotic portion and destruction of the adjacent bone trabeculae may be noted (hematoxylin and eosin stain).

Fig. 1-F: A similar nodule (× 227) from the vertebra in which the central necrotic portion has become cystic (hematoxylin and eosin stain).

there were scattered areas of fibrosis. The posterior papillary muscle contained an area of necrosis surrounded by a zone of fibrous tissue. Adjacent muscle fibers had hypertrophied nuclei, and contained increased amounts of lipochrome pigment. Sections of the epicardium revealed a fibrinopurulent exudate which was undergoing organization by fibroblasts from the epicardial surface. An occasional giant cell could be observed. In other areas the inflammatory process appeared older, with the formation of fibrotic granulomata. Sections of the right coronary artery, two centimeters from its orifice, revealed an atheroma which partially occluded the lumen.

Sections of the lungs revealed phagocytes laden with hemosiderin, oedema, and polymorphonuclear cells in many of the alveoli. In sections of the right upper lobe, organized thrombi were observed in some of the branches of the pulmonary artery.

In sections of the liver, there was a mild degree of infiltration with fat. In the center of many of the lobules, necrosis of liver cells was associated with an increased number of lymphocytes, polymorphonuclear cells, and Kupffer's cells. In sections of the duodenum, ulceration of the mucosa and submucosa down into the muscularis and diffuse suppurative inflammation of the inner layer of the muscularis with destruction of the muscle fibers were noted.

In sections of many lymph nodes, the germinal centers were enlarged and active proliferation had occurred. The interfollicular tissue and the sinuses contained many phagocytes filled with hemosiderin. In the sinuses of some of the lymph nodes there were also numerous lymphocytes and polymorphonuclear cells.

In sections obtained from the synovial membrane of the right knee, the surface was ulcerated and covered by a fibrinous exudate in the meshes of which were numerous mononuclear cells. The exudate was undergoing organization by fibroblasts, and a number of giant cells were observed. The synovial membrane itself was the site of a chronic inflammatory process characterized by markedly increased vascularity and focal and diffuse collections of lymphocytes and a few plasma cells.

Sections taken through the second right tarsometatarsal joint revealed extensive destruction of the cartilaginous surface with pannus formation. The granulomatous inflammatory process had invaded and destroyed the underlying bone. The synovial membrane was thickened and vascularized and contained large numbers of lymphocytes and plasma cells. At the attachment of the synovial membrane to the cartilage there was a granulomatous nodule consisting largely of fibroblasts.

Sections of the twelfth thoracic vertebra revealed extensive necrosis of marrow and cancellous bone. At the periphery of the necrotic region there was a granulomatous inflammatory process characterized by numerous fibroblasts, lymphocytes, phagocytes and a few plasma cells. Within the granulomatous tissue were foci of necrosis with an infiltration of polymorphonuclear leukocytes. A number of blood vessels in the necrotic portion were thrombosed. Sections of the third lumbar vertebra revealed numerous granulomatous nodules which consisted of a central necrotic area and a peripheral zone of large histiocytes and fibroblasts, radially arranged and presenting a palisaded appearance (Fig. 1-E). These fibroblasts and histiocytes had long processes which extended into the necrotic area. In some of the nodules the central necrotic portion had become partially cystic (Fig. 1-F). Many of the smaller nodules consisted largely of fibroblasts, and necrosis was not a prominent part of the process. These lesions appeared identical with those in the myocardium.

The following anatomical diagnoses were made: coronary atherosclerosis with partial occlusion and coronary insufficiency; old infarcts on the posterior wall of the left ventricle and posterior papillary muscle; oedema of lungs with bronchopneumonia; chronic rheumatoid arthritis; rheumatoid granulomatous nodules of the twelfth thoracic and third lumbar vertebrae with compression fracture of the twelfth thoracic vertebra; rheumatoid granulomatous myocarditis and pericarditis; bilateral hydrothorax (1,000 cubic centimeters each); hypertrophy of the heart (550 grams, normal 284 grams); organized thrombus in the artery to the right upper lobe of the lung; toxic central necrosis of liver and recent ulceration of the duodenum.

The roentgenographic demonstration of destructive lesions in the vertebrae together with the Bence-Jones protein in the urine suggested multiple myeloma as a probable diagnosis. Subsequent efforts to confirm this impression, however, were fruitless. Examination of the stained smear of the peripheral blood, sternal aspiration, and direct aspiration of the lesion in the twelfth thoracic vertebra failed to support the diagnosis of multiple myeloma, and a definite diagnosis could not be made until necropsy was performed.

At necropsy it was apparent that the immediate cause of death was congestive heart failure, oedema of the lungs, and bronchopneumonia. The congestive failure was probably the result of coronary atherosclerosis with coronary insufficiency and infarcts of the myocardium. However, the most interesting lesions were not those which precipitated the fatal outcome but the granulomatous lesions which were a part of the underlying rheumatoid arthritis. These granulomatous lesions had involved not only the more commonly affected sites, such as subcutaneous tissue, synovial membranes, and subchondral bone,

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. Lateral roentgenogram showed rheumatoid activity on the margins of the bodies of the tenth, eleventh, and twelfth thoracic vertebrae.

Fig. 2-B: Oblique view, made six years later, showed extensive granulomatous destruction of the tenth and eleventh thoracic vertebrae.

but also the less commonly affected regions such as the heart and pericardium. Most unusual was the presence of the granulomatous lesions in the vertebrae in this case.

Even at necropsy the gross examination failed to reveal the nature of the process which had caused destruction of the vertebral bodies and the pericarditis. The lesions in the vertebrae were interpreted as myelomatous in character until histological examination revealed their true nature. It is unfortunate that cultures were not made from the granulomatous lesions in the vertebrae. Cultures of the pericardial exudate were made but were negative for bacteria. Sections of the granulomatous lesions were appropriately stained and examined for micro-organisms and fungi, but none were found. These facts and the simultaneous occurrence in multiple sites of lesions histologically similar to subcutaneous nodules of rheumatoid arthritis strongly suggested that the lesions in the vertebrae were in fact the counterpart of these well-known rheumatoid nodules.

Although these lesions have not to our knowledge been previously described in vertebrae, we have had under clinical observation three additional patients with rheumatoid spondylitis who presented roentgenographic evidence of similar destructive lesions in the vertebrae. In all three of these patients, clinical diagnostic procedures failed to suggest any cause other than the presence of rheumatoid granulomatous nodules to account for the destructive lesions in the vertebrae.

CASE 2. The patient was first seen at the Clinic in 1944 at the age of forty-three years. At that time he exhibited characteristic findings of rheumatoid spondylitis, symptoms of which had been present for twenty-one years. In addition there was roentgenographic evidence of destructive lesions on the margins of bodies of the tenth, eleventh, and twelfth thoracic vertebrae (Fig. 2-A). These lesions remained relatively asymptomatic until six years later, when moderately severe pain developed in the lower part of the thoracic

FIG. 3

FIG. 4

Fig. 3: Case 3. Lateral roentgenogram showed active granulomatous lesion of the third and fourth lumbar vertebrae and at the superior margin of the fifth lumbar vertebra (with needle inserted).

Fig. 4: Case 4. Lateral roentgenogram showed rheumatoid granulomatous destructive lesion of the tenth and eleventh thoracic vertebrae.

region of the back. At that time the destructive lesions in the tenth and eleventh thoracic vertebrae were larger (Fig. 2-B). The application of a body cast in February 1950 afforded relief from pain in the thoracic region. Re-examination in May 1950 revealed no change in the roentgenographic appearance of the vertebral lesions.

CASE 3. The patient began to have symptoms of rheumatoid spondylitis in 1929 at the age of twenty-two years. In December 1949, there occurred an episode of more acute pain in the lumbar region of the back. Examination in January 1950 revealed changes typical of rheumatoid spondylitis. Roentgenograms also revealed destructive lesions involving the third and fourth lumbar vertebrae, slight narrowing of the third lumbar interspace, and some depression of the superior vertebral plate of the fifth lumbar vertebra (Fig. 3). Re-examination ten months later revealed the destructive lesions in the vertebrae to be somewhat smaller.

CASE 4. The patient, a brother of one of these patients (Case 3), began to have symptoms of rheumatoid spondylitis in 1940 at the age of twenty-three years. In 1948, he had an episode of increased pain low in the thoracic region of the back for two days. In January 1951, examination at the Clinic revealed characteristic findings of rheumatoid spondylitis. In addition, marked destructive lesions involving the tenth and eleventh thoracic vertebrae were demonstrated by roentgenogram (Fig. 4). These lesions were interpreted as being due to rheumatoid granulomatous nodules. There was no appreciable change in the roentgenographic appearance of the vertebral lesions in May 1951.

In the light of this experience it seems important to consider rheumatoid granulomatous nodules in the differential diagnosis of destructive lesions of the vertebrae in cases of rheumatoid arthritis.

Other vertebral lesions from which rheumatoid granulomatous nodules need to be differentiated include multiple myeloma, metastatic carcinoma, osteoporosis, compression fracture, and specific infectious granuloma as seen in tuberculosis, fungus infection, brucellosis, or typhoid fever.

In Case 1, the lesion could not be diagnosed definitely by clinical or roentgenographic investigation. Multiple myeloma was suspected. In the other three cases, the involvement of adjacent portions of contiguous vertebrae simulated the lesions of tuberculosis more than those of metastatic carcinoma or myeloma. It may perhaps be significant that in all four cases the lesions evident in the roentgenograms were in the anterior portion of the body of the vertebrae, although in the one case studied at necropsy, lesions were found in other parts of the vertebral body also.

SUMMARY

In a case of rheumatoid arthritis, granulomatous nodules were observed clinically in the subcutaneous tissue and at necropsy in the synovial membranes, pericardium, myocardium, subchrondral bone, and vertebrae. The granulomatous process in the vertebrae in this case caused compression fracture of the twelfth thoracic vertebra and appeared similar roentgenographically to such other destructive lesions as multiple myeloma, metastatic carcinoma, and tuberculosis. This case, together with three others reported briefly, emphasizes the fact that the granulomatous inflammation which is so commonly observed in the subcutaneous tissues and occasionally in the viscera of patients with rheumatoid arthritis may also involve the vertebrae. This fact is important in the consideration of the differential diagnosis of destructive lesions of vertebrae in patients with rheumatoid arthritis.

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ARTHROPLASTY OF THE ELBOW

An End-Result Study *

BY ROBERT A. KNIGHT, M.D., AND I. L. VAN ZANDT, M.D., MEMPHIS, TENNESSEE

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During the past year, the authors have evaluated the results in forty-five of ninety-three patients on whom arthroplasty of the elbow had been performed by members of the Campbell Clinic during the years 1921 to 1948. An analysis of these patients presents some informative generalizations.

INDICATIONS

Arthroplasty is indicated in fibrous or bony ankylosis of the elbow, in partial ankylosis with insufficient motion, and in partial ankylosis where pain is a disabling factor. It is

TABLE I

LENGTH OF FOLLOW-UP

Etiology of Ankylosis	Total No. of Cases	Three to Five Years	Six to Ten Years	Eleven to Twenty Years	Twenty-one to Thirty Years
Atrophic arthritis	7	1	5		1
Infective arthritis	14		2	8	4
Closed fractures and fracture-dislocations	13	2	1	7	3
Open fractures and fracture-dislocations	10	1	3	5	1
Miscellaneous: osteochondromatosis	1				1
Total	45	4 (9 per cent.)	11 (24 per cent.)	20 (44 per cent.)	10 (22 per cent.)

indicated if the patient is between twenty and fifty years of age; when the ankylosis, whether partial or complete, is the result of (1) acute infective arthritis, either hematogenous or the result of a direct wound, (2) fractures or fracture-dislocations of the elbow which have resulted in pain or excessive limitation of joint motion, or (3) atrophic arthritis.

CONTRA-INDICATIONS

Arthroplasty is contra-indicated: (1) in those cases in which the patient requires a strong, stable extremity for hard physical labor,—that is, if strength and stability are more important than motion; (2) in tuberculosis; (3) in osteomyelitis, either hematogenous or associated with open fractures; (4) in extra-articular ankylosis, such as may follow an infected open supracondylar fracture of the humerus with antecubital scarring and capsular contracture; and (5) in cases of marked muscle weakness, particularly of the biceps and forearm muscles. This latter condition is usually the result of long-continued inactivity, such as is found in advanced cases of atrophic arthritis.

* Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 23, 1951.

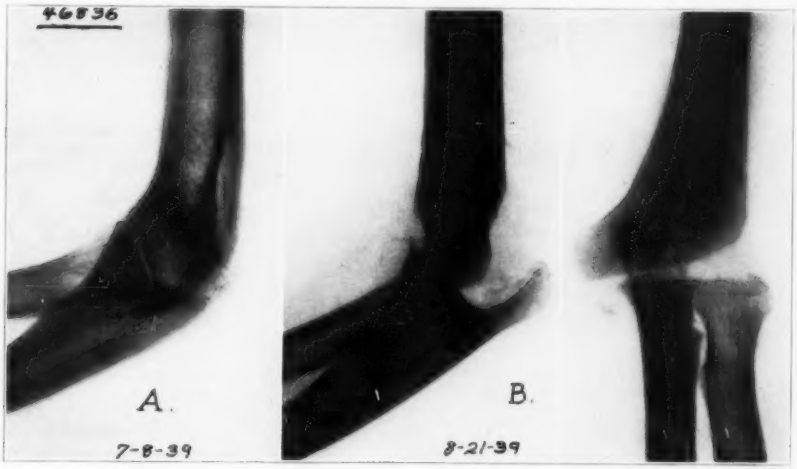

FIG. 1-A FIG. 1-B

Fig. 1-A: Lateral view of elbow shows solid bony ankylosis of the ulnohumeral joint following pyogenic infection; there was also fibrous ankylosis of the radiohumeral joint.

Fig. 1-B: Roentgenograms made immediately after arthroplasty. Note excessive valgus of humerus and slight lateral subluxation of joint.

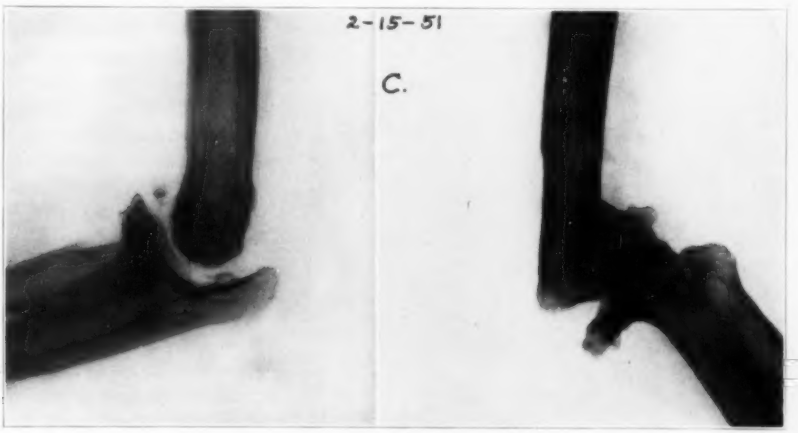

FIG. 1-C

Eleven years after arthroplasty, marked lateral subluxation occurred. Fascial stabilization was necessary after a revision amounting to partial resection of the humerus had been performed. Despite marked lateral instability of the joint, the functional result was good.

TECHNIQUE OF OPERATION, AFTER-CARE, AND COMPLICATIONS

In this series, the Campbell technique was followed, except for such minor modifications as were required in individual cases. The posterior approach to the elbow, developing a tongue of triceps tendon, is now preferred, as it furnishes an adequate exposure without excessive soft-tissue stripping, permits plastic lengthening of the tendon where necessary, and allows isolation of the ulnar nerve with ease. A simple monocondylar joint is fashioned, all of the articular surfaces being reshaped and covered with fascia lata. Denudation of the humeral condyles should be confined to the absolute minimum consistent with satisfactory exposure, thereby limiting postoperative absorption of the humerus. To create an

FIG. 2-A FIG. 2-B

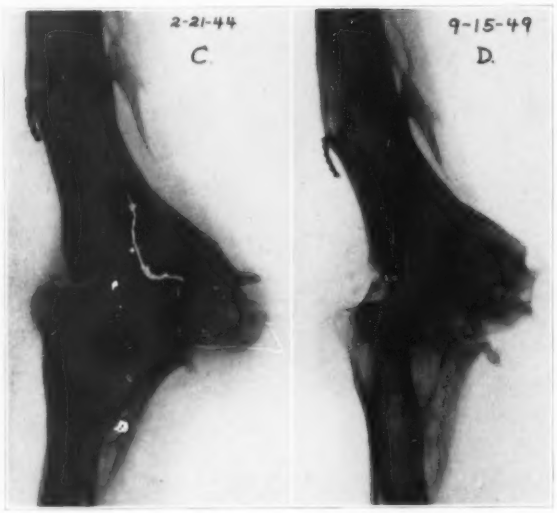

FIG. 2-C FIG. 2-D

Fig. 2-A: Roentgenograms made four years after multiple open fractures of extremity show complete fibrous ankylosis of the ulnohumeral joint. Pronation and supination are free. Note area of rarefaction in lateral condyle of humerus.

Fig. 2-B: Four months after fascial hemi-arthroplasty. The radiohumeral joint has not been disturbed.

Fig. 2-C: Twenty-one months after operation, marked fragmentation and disintegration of lateral humeral condyle.

Fig. 2-D: Seven years after operation, there had been little essential change as shown by roentgenogram, and function was surprisingly good. Results, both roentgenographically and functionally, would have been better had complete fascial arthroplasty been done.

adequate joint space, more bone should be removed from the olecranon and radius and less from the humerus; resection or later absorption of the humerus to a level above the epicondyles will invariably be followed by excessive instability and weakness. No attempt is made to create more than a minimal carrying angle, since the formation of a joint with an increased carrying angle may result in lateral subluxation of the radius and ulna upon the humerus (Figs. 1-A to 1-C).

In all instances, the head of the radius should be resected to a degree commensurate with the amount of bone resected from the ulna, otherwise it will exert an undue amount of pressure upon the capitellum and cause excessive absorption of the lateral humeral condyle or a medial subluxation of the joint (Figs. 2-A to 2-D). Resection of the radial head does not increase joint instability. In twenty-four cases in this series, an attempt was made to restore pronation and supination; in sixteen of these, rotation was restored to a varying but satisfactory degree, supination usually being regained to a greater degree than pronation.

Even though the elbow is ankylosed in extension, it is rarely necessary to lengthen the triceps tendon. If the olecranon fossa is deepened sufficiently, it will usually be found that apparent soft-tissue contractures have been satisfactorily relieved. Triceps lengthen-

Fig. 3-A: Solid bony ankylosis, resulting from severely infected open fracture.

Fig. 3-B: Two months after arthroplasty; infection had been relighted and fascia had been lost.

Fig. 3-C: Sequestration and absorption of humerus resulted in grossly unstable joint. Fascial stabilization failed when the infection was again relighted. Calcification about the ulnohumeral pseudarthrosis aided in stabilization of the joint.

Fig. 3-A

Fig. 3-B

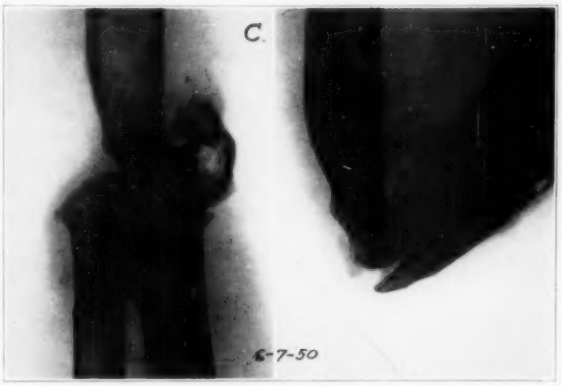

Fig. 3-C

ing should be avoided if possible; in every case examined, there was some relative or actual weakness of the triceps muscle; several patients were unable to extend the elbow actively against gravity.

After operation, the extremity is immobilized in a long arm cast with the elbow at a right angle and the forearm in mid-position. An abduction humerus splint is then applied to prevent rotational stresses and strains. At the end of two weeks, the splint and cast are removed, a posterior elbow splint with straps and buckles is fitted, and mobilization of the joint is begun. Ideally, this consists of supervised active motion, preferably against mild resistance, and gentle passive motion. The strength of the forearm muscles, as well as of the elbow flexors and extensors, must be developed, and at no time should passive motion exceed active motion to any appreciable degree; otherwise, the joint will become unstable and the muscles will lose strength. Four weeks after operation, if strength and stability are adequate, the splint may be discarded except at night. During the day, a sling may be used as necessary.

In this series, postoperative infection was the one disastrous complication (Figs. 3-A to 3-C). When this occurred, it was necessary to remove the fascia immediately. If the infection persisted for more than three weeks, a poor result or failure invariably followed. Persistent infection led to soft-tissue scarring, bone absorption, and sequestration. When infection developed, the distal end of the humerus was involved primarily and acted as a typical sequestrum, while the radius and ulna withstood the ravages of the infection with little if any damage. This difference in reaction to infection was presumably due to the fact that dissection of the radius and ulna was minimal, while the humerus was often extensively stripped of its soft tissues.

Delayed ulnar palsy, secondary to a valgus deformity, occurred in three patients. Transposition of the nerve was successful in each case.

Fascial stabilization of the joint was performed in three cases, with marked improve-

TABLE II

RESULTS OF ARTHROPLASTY OF THE ELBOW

Etiology of Ankylosis	Total No. of Cases	Good	Fair	Poor	Failure
Atrophic arthritis	7	4	3		
Infective arthritis	14	8	3	1	2
Closed fractures and fracture-dislocations	13	10	2		1
Open fractures and fracture-dislocations	10	3	2		5
Miscellaneous: osteochondromatosis	1				1
Total	45	25 (56 per cent.)	10 (22 per cent.)	1 (2 per cent.)	9 (20 per cent.)

ment in one, moderate improvement in another (Figs. 1-A to 1-C), and failure in the third case, in which infection supervened with resulting loss of fascia and bone (Figs. 3-A to 3-C).

EARLY AND LATE RESULTS OF ARTHROPLASTY

The average patient will regain his motion within six months to a year after operation, and his maximum degree of strength in approximately one year. Unless there is progressive absorption of the humeral condyles, the elbow will remain essentially unchanged in range of motion, strength, and endurance with the further lapse of time. Bone absorption was seen infrequently and, when it occurred, it was the result of either a postoperative infection or osteoporosis (Fig. 4). On the other hand, proliferative or hypertrophic bone changes

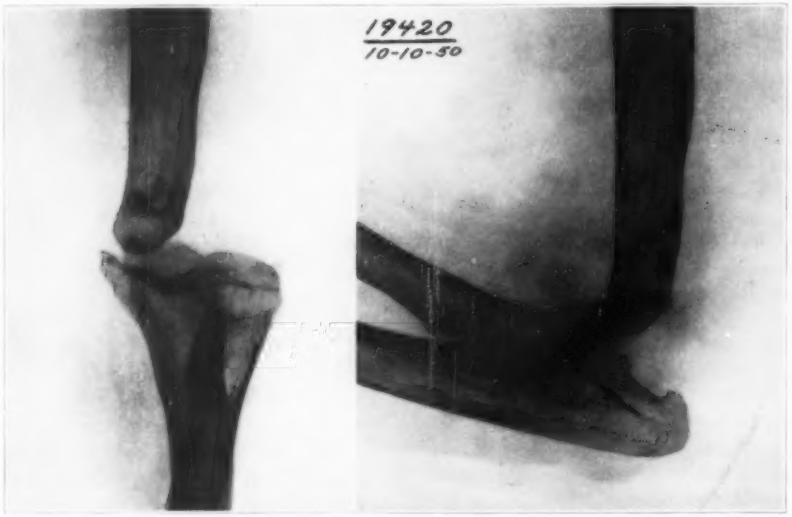

FIG. 4

Twenty-four years after arthroplasty. Patient had had severe generalized atrophic arthritis, with marked degree of osteoporosis. There has been marked absorption of the humerus; joint was grossly unstable.

Fig. 5-A: Neglected Monteggia fracture with calcification about the head of radius.

Fig. 5-B: Fibrous ankylosis of elbow developed following excision of head of radius, although joint was never infected.

Fig. 5-C: Excellent result eleven years after fascial arthroplasty. Extensive proliferative joint changes. Patient has 120 degrees of flexion and extension with normal pronation and supination.

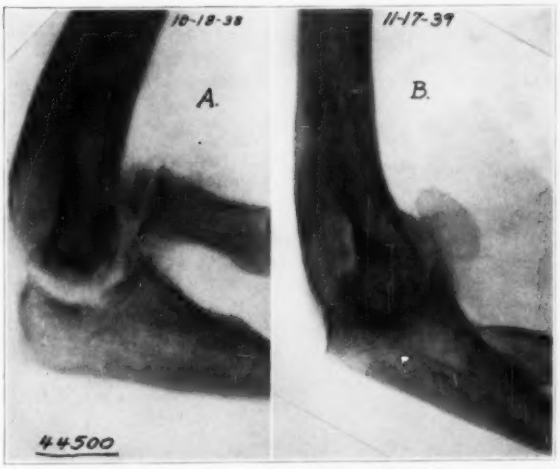

Fig. 5-A Fig. 5-B

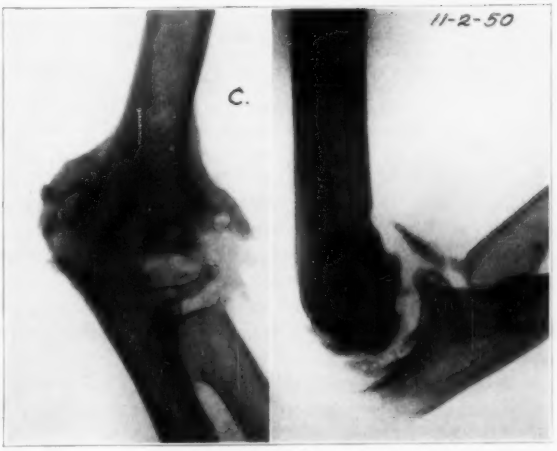

Fig. 5-C

were found quite frequently, gradually developing with time and use, but never to such an extent that pain or progressive limitation of motion could be attributed to them (Figs. 5-A to 5-C).

In some instances, there was progressive deepening and enlargement of the olecranon fossa, and in one instance there was hypertrophy of the coronoid process. Otherwise, the radius and ulna showed little change except for development of the mild proliferative changes noted above. Medial subluxation occurred in five instances and lateral subluxation was found in eight cases. Selective absorption of one of the humeral condyles was the cause in some instances (Fig. 2-C); in one case, the lower end of the humerus was remodeled in an excessively oblique fashion (Fig. 1-C); and in the remainder, no definite cause was found. Ordinarily, subluxation was of little importance if bone absorption was minimal.

The roentgenographic appearance of an elbow joint following arthroplasty does not necessarily parallel the functional result. Even though the irregularity of the joint surfaces may be so great that there is apparent incongruity, the functional result may be quite satisfactory (Figs. 5-A to 5-C). An interpretation of the development of the new joint would indicate that only sufficient bone should be removed to permit a satisfactory range of motion in the joint, probably three-fourths of an inch when the joint surfaces are gently distracted, and that, after the operation, diligent efforts of the patient must be directed primarily to the development of muscle strength rather than motion.

A range of motion of from 90 to 120 degrees, in a useful arc, is ideal. A greater range of motion than this is usually accompanied by instability, increased weakness, and ease of fatigue. In no case was pain a factor of importance, even though extensive proliferative joint changes might be noted roentgenographically.

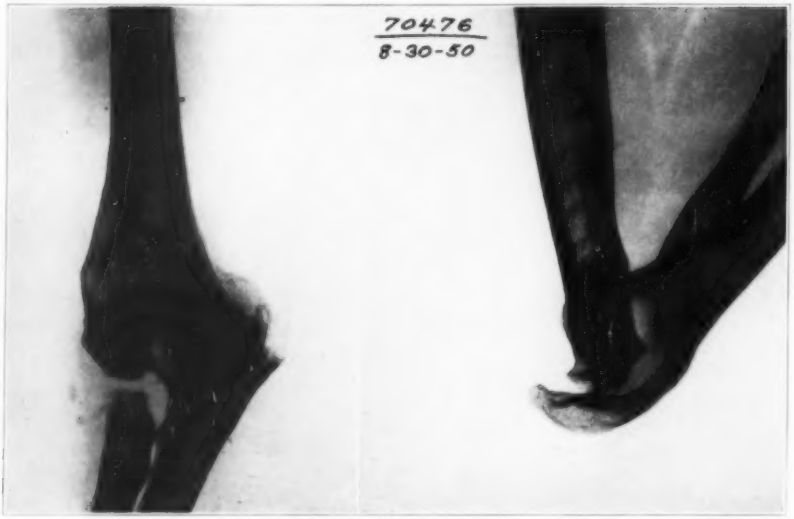

FIG. 6

Five years after arthroplasty for ankylosis due to atrophic arthritis. Note lack of excess bone absorption. Patient has good musculature and result is good.

RESULTS

The following designations have been employed in classifying the end results:

Good indicates a range of motion of from 90 to 120 degrees in a useful arc, with good stability and muscle strength;

Fair indicates a range of motion of from 70 to 90 degrees, with satisfactory stability and with sufficient strength for ordinary activity;

Poor indicates a limited range of motion, usually of from 40 to 70 degrees, without instability, or an adequate range of motion with instability due to excessive condylar absorption.

The result is considered a *failure* if the joint is flail, or if the joint has become re-ankylosed or has required arthrodesis because of weakness or instability.

ANALYSIS OF RESULTS

Among the seven cases of atrophic arthritis, ankylosis occurred at 135 degrees of extension or more in four patients, while there was bony ankylosis at a right angle in the remaining cases. All of these patients had multiple joint involvement, but the disease was quiescent at the time of operation. In no instance was the operation followed by a local or general exacerbation of the arthritic process. The range of motion and stability after arthroplasty were dependent upon the condition of the periarticular structures and upon the rehabilitative potential of the elbow flexors and extensors. Those patients with good ligament and muscle tissue obtained stable and relatively strong joints with good motion (Fig. 6). In two of the patients in whom the results were considered fair, the opposite elbow was completely ankylosed and the patients were grateful and pleased with the results.

There were two failures among the group of patients whose ankylosis followed an infective arthritis. One patient had progressive loss of motion with ultimate re-ankylosis, for which no cause could be found. Another patient had a range of motion of 60 degrees with good stability, but requested arthrodesis because of the lack of endurance of the joint for heavy farm work.

Thirteen patients had closed fractures or fracture-dislocations as a cause for their elbow disability. In general, the results were good, the one failure being in a patient who had an extra-articular ankylosis as a result of a malunited supracondylar fracture of the humerus; at operation, the anterior joint capsule was found to be tremendously thickened and scarred.

Of the ten whose ankylosis followed open fracture and fracture-dislocations, four patients would now be considered unsatisfactory candidates for arthroplasty. One of these had severe soft-tissue loss and gas gangrene with massive scarring of the soft tissues, as well as a bony ankylosis; one had a chronic lymphoedema of the forearm, and two had primarily extra-articular ankyloses. Two failures were the result of postoperative infection with loss of bone and fascia. With proper selection of cases and with the judicious use of antibiotics, the results in this group should approximate those in the group with ankylosis following open fractures.

The patient in the miscellaneous group in whom arthroplasty failed was an unsuitable candidate for arthroplasy. During operation for an extensive osteochondromatosis in a woman twenty-two years old, destruction of the articular cartilage was encountered and a primary arthroplasty was performed. The tumor recurred, involving the lower end of the humerus. Resection of the humerus was performed two and one-half years after arthroplasty, preventing further recurrence of the tumor but resulting in a flail joint.

CONCLUSIONS

A survey of arthroplasty of the elbow has been made, forty-five patients having been evaluated clinically and roentgenographically an average of fourteen years following operation. The cases were not selected, and none was excluded from the series. Among these patients, 56 per cent. secured good results, 22 per cent. fair results, and 22 per cent. obtained unsatisfactory results. The roentgenographic findings in most instances fail to give a true picture of clinical function. The functional and roentgenographic results, with few exceptions, show little change after the first year following operation. It is to be concluded that fascial arthroplasty of the elbow, properly performed in selected cases, offers a reasonable expectation of 70 to 120 degrees of motion in a useful range, with good strength and stability, and with little if any pain except after strenuous use.

DISCUSSION

DR. LEO S. LUCAS, PORTLAND, OREGON: Cases of extra-articular fibrosis with loss of motion at the elbow joint need not be classified as unsuitable for reconstruction, provided that the amount of bone removed approaches that taken in a resection and that the musculature is capable of being strengthened by intensive physiotherapy.

Basically the success of an arthroplasty or resection depends upon muscle strength. An evaluation should be made after six or eight weeks of intensive preoperative muscle-setting and tension exercises. Careful postoperative supervision should continue over several months and, if possible, the exercises should be controlled by a competent physiotherapist.

We believe that the head of the radius should be removed in practically every instance; no matter which type of operation is done, it is our practice to transpose the ulnar nerve.

A review of our cases in older children and adults has led us to believe that resection may be preferable to arthroplasty in any case where reconstruction of the elbow joint is desirable. A mild degree of instability following resection does not represent great disability, provided that the patient obtains a joint with a good range of motion, good muscle strength, and freedom from pain.

It has been our experience that many patients, after resection of the elbow, are capable of carrying on hard manual labor, can engage in athletic sports, and do not become fatigued as easily as many of those who have had arthroplasties.

In arthroplasties, as well as in resections, we have used some form of interposing medium to cover the ends of the denuded bone. In recent years we have used split layers of the triceps to cover the ends of the bones in resections. We feel that this is superior to the use of fascia or any other foreign material, and has eliminated infection in our cases.

The muscle flap is viable; it covers the bones long enough to allow for the production of a fibrous covering; it prevents bleeding from the bone ends and allows one to snug the joint firmly when closing it. The

triceps power has not been affected by using the flaps in any way. We feel that, since we have used this method, secondary absorption of the bone ends has been much less evident.

The authors are to be complimented on their thorough study and fair analysis of arthroplasties, followed sufficiently long to permit conclusions of value.

DR. C. R. ROUNTREE, OKLAHOMA CITY, OKLAHOMA: It has been my pleasure to follow for twenty years one case which has been reported this morning. This patient was operated upon by Dr. Campbell. A very severe multiple rheumatoid arthritis with involvement of the opposite elbow subsequently developed, but at no time did the elbow ever show any evidence of the disease, nor did it manifest any pain or seem to be involved in the arthritic process. I should like to ask Dr. Knight if he has any comment to make on this point.

DR. JESSE T. NICHOLSON, PHILADELPHIA, PENNSYLVANIA: My experience in regaining elbow motion has followed resection of the elbow joint. Flexion has not been a problem unless more than two inches of the distal portion of the humerus was resected or the same amount of the proximal end of the ulna. These resections might result in inability to flex the elbow against gravity more than sixty degrees. With less than two-inch resections, regardless of the distribution, ninety or more degrees of flexion was obtained against gravity. Limited or lost was the power to pronate the forearm or to extend the elbow against gravity. I would like to have Dr. Knight comment upon these motions in regard to the arthroplasties he has reviewed.

DR. PHILIP D. WILSON, NEW YORK, N. Y.: For many years I have performed arthroplasty in preference to resection. In my early cases I used fascia lata and during the last two years I have used nylon. The principal thing that I have always noted with fascial arthroplasties is the slow restitution of function. The reason is that the fascia becomes adherent and more time is required to develop motion than with nylon. I have used the Kocher incision and have never exposed the ulnar nerve in doing it, dissecting close to the bone; I have never had an ulnar-nerve injury. The nerve transposition is not necessary in my opinion. Some of the best functional results which I have had from arthroplasty have shown the poorest results when examined by x-ray. There has been marked absorption of bone and in some cases actual dislocation of the ulna to one side of the humerus, and yet patients have been extremely happy.

In my own hands, resection has been reserved for those cases in which arthroplasty had failed — and we have had failures. Doing a resection in those cases often has given a successful result.

DR. KNIGHT (closing): In earlier years, it was our practice to approach the elbow joint by a posterolateral subperiosteal route, unless it was anticipated that lengthening of the triceps tendon might be desirable. More recently, the posterior triceps muscle-splitting incision, developing a tongue of triceps tendon, has been used, but only rarely is it necessary to lengthen the triceps muscle. Where the triceps has been lengthened (or where an excess amount of bone has been removed), weakness of extension has persisted.

The ulnar nerve is not routinely isolated or exposed unless scarring makes this desirable. No difficulty has been encountered when a subperiosteal approach is used.

It is interesting to find that function is regained more promptly following fascial arthroplasty of the elbow than of the hip or knee, that the "end result" is reached at an earlier period, and that the joints do not deteriorate or degenerate with the promptness or consistency found in the fascial arthroplasties of the hip and knee.

We have had no experience with nylon as a medium for interposition, but we feel that it would be an excellent substitute where fascia is not available.

The postoperative development of muscle strength cannot be overemphasized. The pronatory function of the forearm flexors, as mentioned by Dr. Nicholson, must be remembered during the period of postoperative rehabilitation.

Dr. Rountree has discussed the interesting phenomenon in which the joint that has been the site of a fascial arthroplasty is usually spared to a large extent, if not completely, should atrophic arthritis subsequently develop.

I wish to thank the discussors for their interest and for their contributions to the presentation.

A CLINICAL EVALUATION OF SUBCUTANEOUS ACHILLES TENOTOMY AS AN AID IN THE TREATMENT OF INTERMITTENT CLAUDICATION *†

BY DAVID I. SCHWARTZ, M.D., LEWIS L. PENNOCK, M.D., CARL J. PESSOLANO, M.D., AND DONALD S. LITTMAN, M.D., PITTSBURGH, PENNSYLVANIA

From the Veterans Administration Hospital, Aspinwall, and the University of Pittsburgh School of Medicine, Pittsburgh

The relief of calf pain caused by intermittent claudication has long been a problem. Many forms of treatment have been used for alleviation of this condition with varying degrees of success but usually with disappointing results.

For the purposes of this paper, the pain in intermittent claudication is defined as that which is experienced by patients suffering from chronic obliterative vascular disease and hence is attributed to the blood supply to the muscles of the lower extremities being insufficient to meet the demands made upon the vascular system during periods of muscular activity. The general aim of the treatment is either to increase the available blood supply to the extremities or to lessen the demands for blood by decreasing muscular activity. To increase the blood supply, vasodilator drugs are sometimes administered. Lumbar sympathetic nerve blocks and lumbar sympathectomies are also undertaken for the same purpose. Measures intended to lessen the demands for blood take the form of reduced general activity or of instruction in ambulation without the use of the calf muscles. Since these latter forms of treatment are not advisable in all cases and since many patients do not respond favorably to the former, further measures have been sought for the alleviation of pain due to ischaemia.

Such a procedure was reported in 1949 by Boyd, Ratcliffe, Jepson, and James [1]. These men, after learning from the veterinarian that sectioning of the tendon near the hoof relieved lameness in horses caused by vascular disease, decided to apply the principle in the treatment of human patients afflicted with a similar ailment. Of twenty-four patients treated by tenotomy of the tendo achillis, the results in twenty-two were classified as good, in the remaining two as improved.

Because of the success recorded in this study, a clinical evaluation of subcutaneous Achilles tenotomy as an aid in the treatment of intermittent claudication was undertaken at the Veterans Administration Hospital in Aspinwall. The number of patients so treated is only ten. In spite of this, the results have been so favorable that we feel justified in reporting them at this time in the hope that the procedure will be more widely accepted.

PROCEDURE

In those cases in which the patients have not responded well to efforts at increasing the blood supply to the muscles of the legs, subcutaneous Achilles tenotomy is performed, either unilaterally or bilaterally, as indicated. In this series, this surgical procedure was carried out under spinal anaesthesia, the patient lying prone on the table. A sharp, thin tenotome is inserted subcutaneously on the medial side of the Achilles tendon about one-quarter inch proximal to the heel and is passed just anterior to the tendon in order to divide it completely by using a few short, quick, upward strokes of the instrument. Bleeding is negligible; no sutures are required in the puncture wound. A small sterile dry dressing is applied. The entire operation is completed within a few minutes. In our experience, the risk has been minimal.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1951.

† Published with the approval of the Chief Medical Director of the Veterans Administration. The statements and conclusions of the authors do not necessarily reflect the opinion of the Veterans Administration.

TABLE I

Age and Color	Duration of Claudication (*Years*)	Absent Pulses		Oscillometric Readings				Average Distance Covered before Beginning of Claudication	Results
				Calf		Ankle			
		Right	Left	Right	Left	Right	Left		
50 W	7	Dorsalis pedis	Dorsalis pedis	1½	6	1	1	1 city block	Good
57 W	5	Dorsalis pedis Tibialis posterior Popliteal	Dorsalis pedis Tibialis posterior Popliteal	½	½	¼	¼	3 city blocks	Fair
60 W	2	Dorsalis pedis Tibialis posterior Popliteal	Dorsalis pedis Tibialis posterior Popliteal	¼	0	Trace	0	180 feet at 120 steps per minute	Fair
59 W	1½	Dorsalis pedis Tibialis posterior Popliteal	Dorsalis pedis Tibialis posterior Popliteal	0	0	0	0	400 feet	Good
62 W	1	Dorsalis pedis Tibialis posterior	Dorsalis pedis Tibialis posterior	2	½	¼	0	60 feet	Good
55 W	"Years"	Dorsalis pedis Tibialis posterior	Dorsalis pedis Tibialis posterior	Trace	1¼	Trace	1	4 city blocks	Good
59 W	"Years"	Dorsalis pedis Tibialis posterior	Dorsalis pedis Tibialis posterior	1½	3½	¼	½	300 feet	Good
58 C	2	Dorsalis pedis Tibialis posterior	Dorsalis pedis Tibialis posterior	Trace	2	0	1	260 feet	Good
60 W	7	Dorsalis pedis Tibialis posterior Popliteal	Dorsalis pedis Tibialis posterior Popliteal	0	0	0	0	190 feet	Good
52 W	"Years"	Dorsalis pedis Tibialis posterior Popliteal	Dorsalis pedis Tibialis posterior Popliteal	1½	½	¾	Trace	1 city block	Good

POSTOPERATIVE MANAGEMENT

The day after this procedure the patients are usually ambulatory without the aid of braces, but may need the support of a cane. The more timid ones may not walk until the second or third day after the operation. All are given the benefit of instruction in balance and gait. As prophylactic anticoagulant therapy, dicoumarol is started on the day of the operation and continued for about five days.

ANALYSIS OF CASES

All patients treated were males between fifty and sixty-two years of age and all were victims of arteriosclerosis obliterans (Table I). Nine of the ten patients had bilateral involvement. Duration of the claudication before surgery ranged from one to seven years. The ability to walk before claudication set in was short and definte in every instance. Oscillometric readings were made before surgery and in every case revealed marked impairment. All of the patients operated upon had been receiving conservative treatment without sufficient relief of symptoms. In three cases superficial thrombophlebitis developed postoperatively, which responded well to anticoagulant therapy with heparin and dicoumarol. After the inauguration of prophylactic anticoagulant therapy this complication did not occur again in this series.

FIG. 1

Showing defect of tendon as result of the tenotomy.

RESULTS

In every instance considerable improvement has been noted clinically, and every patient is satisfied with the results of the operation. Although the pain of intermittent claudication in the calf has disappeared, the patients report that they tire generally and must rest after walking varying distances. This is not surprising when one considers the age group of the patients and the condition of their cardiac, peripheral vascular, and muscular systems.

The gait is always altered after the operation. However, with proper instruction a good gait is attained within a reasonably short period of time and is maintained without the aid of braces. The visible defect in the Achilles tendon remains. However, fairly good plantar flexion is noted to be present in a matter of months after surgery (Fig. 1).

CONCLUSIONS

It is our considered opinion that this procedure is a valuable aid in the treatment of intermittent claudication. The operation can be carried out in a few minutes with minimal risk and requires no cooperation on the part of the patient except his willingness to receive instructions regarding balance and gait. While the procedure does nothing to improve the blood supply to the lower extremities, it does eliminate the ischaemic pain in the calf muscles.

Although the series of cases is small and the period of follow-up is short, we hope that our results will stimulate interest in the procedure.

1. BOYD, A. M.; RATCLIFFE, A. H.; JEPSON, R. P.; and JAMES, G. W. H.: Intermittent Claudication. A Clinical Study. J. Bone and Joint Surg., **31-B**: 325–355, Aug. 1949.

DISCUSSION

Dr. Leonard T. Peterson, Washington, District of Columbia: Since I have had no cases severe enough or otherwise suitable, I have not performed tenotomy for this condition. Several questions arise, however, in considering this operation: (1) Has there been any disturbance of balance in standing or walking? (2) Does the elimination of pain remove any warning factor, so that these patients are likely to overexert and therefore suffer early gangrene? Have any of these patients had to undergo amputation? One would expect bilateral tenotomy to be much more disabling than the report indicates.

Dr. Geza De Takats, Chicago, Illinois: Mr. Alexander Boyd of Manchester, while listening to local gossip in a country inn, learned that in the latter part of the nineteenth century a general practitioner did all his rounds on horseback and kept his horses until they were too lame to work, whereupon he divided a tendon near the hoof and gained from them another five years of work. The term "intermittent claudication" has been borrowed from veterinary medicine, and a French veterinarian, Bouley, described the syndrome in 1831.

Dr. Schwartz and his associates showed us a rather striking demonstration of what subcutaneous Achilles tenotomy can do for patients with advanced claudication. I can perhaps best discuss his paper briefly by relating what our clinic has done over a period of twenty-five years in trying to manage this dominant symptom of obliterative vascular disease.

In the first place, we have done over 300 lumbar ganglionectomies for peripheral vascular sclerosis, primarily not to increase walking ability but to arrest the disease and prevent gangrene. This is done because release of the normal vasomotor tone greatly benefits the ischaemic extremity, and there is no need to postulate vasospasm in the arteriosclerotic group.

Second, our group has studied the effect, and used extensively the principle, of intermittent hyperaemia. The effect of this treatment, which must last at least three months with a daily treatment of one to two hours, depends mostly on the stage of the disease in which the treatment is undertaken. The four grades of peripheral vascular sclerosis have been described by us as follows:

Grade I: In this group there are no trophic or thermal changes, and the patient is able to walk two to six blocks or more.

Grade II: Patients in this group present a cold extremity and are able to walk less than two blocks.

Grade III: Patients in this group experience claudication after fifty to 100 feet.

Grade IV: Rest pain, cyanosis, and trophic lesions characterize this group.

In the first and second groups sympathectomy is very successful, and we have shown with oscillometric tracings that intermittent venous compression is far more effective in the sympathectomized extremity. Patients in the fourth group invariably will have to undergo amputation after more or less prolonged periods of absolute bed rest. This leaves patients with Grade III vascular sclerosis, on whom this procedure might be tried. To those of you who may be interested in testing the effectiveness of the procedure, I might suggest the following method, which we employed when we cautiously began to use sympathectomies for vascular sclerosis. This is to perform the tenotomy on the worse leg and then let the patient choose whether or not he wants it performed on the other side.

When I discussed this problem with some of my orthopaedic colleagues, they raised the question of a motor disability attending this procedure. If venous thrombosis can be avoided, if circulatory deterioration is kept in check, and if the method is not employed in pregangrenous extremities, the procedure is worth trying, but case selection must be meticulous.

I would like to ask Dr. Schwartz how he explains the high incidence (three out of nine) of venous thrombosis following tenotomy. Is it because the posterior tibial vein is injured—which is not likely—or is it the lack of muscle pump, the most effective mechanism for venous return, which is responsible? Many elderly patients with sclerosis have deep venous insufficiency, and this may be aggravated by tenotomy.

Dr. Schwartz (closing): Dr. Peterson raised the question of balance. Not all of the patients have good balance after tenotomy; they are told before the operation, however, that they are going to lose their balance but will recover it within a short period of time.

In regard to the question whether pain is abolished and with it perhaps a useful signal, certainly nothing is done in this procedure to alter pain sensation. If there is a pain stimulus the patient will feel it. His nervous system is not affected by this procedure.

In regard to patients having to undergo amputation following this tenotomy because of gangrene, I can only say that gangrene has not developed in any of our cases after tenotomy. We have, however, had to turn down some patients in whom we felt gangrene would develop within a short time.

In reference to Dr. De Takats' discussion, we had one patient on whom sympathectomy had been performed who had only a slight improvement in his ability to walk without pain. When we approached him with the suggestion that we cut his tendons his reaction was that, since he had had so little relief from an important operation, he did not feel confident that any further measures would help him.

As to the three cases of phlebitis, I think that our evaluation of these cases was about the same as that of Dr. De Takats. However, since we inaugurated the routine use of anticoagulant therapy postoperatively, we have not had phlebitis develop in any patients.

TREATMENT OF SUPRACONDYLAR FRACTURE OF THE HUMERUS BY SKELETAL TRACTION IN AN ABDUCTION SPLINT

BY ANDREAS HØYER, M.D., OSLO, NORWAY

From Ullevål Hospital Surgical Department III, Oslo*

Supracondylar fracture of the humerus is one of the commonest elbow injuries in children and adolescents. There are three types,—extension, flexion, and comminuted fractures (Fig. 1). The extension type is by far the most common. It is rarely seen after the age of twenty, for in adults a posterior dislocation is sustained instead.

The names "extension" and "flexion" fractures are based on the concept that these fractures result from hyperextension and hyperflexion respectively, but this has proved not to be correct.

The fracture unites almost invariably, and in the majority of cases function of the arm, although not normal, is satisfactory. This is doubtless the reason that so little stress has been placed on the need for an accurate reduction. Holmberg has shown that, if an anatomical reduction is obtained, the result will be perfect, almost without exception.

Angulations are not corrected by subsequent growth except in the case of very young children[14]. The most common deformity following supracondylar fractures is that of cubitus varus. The incidence of this has been reported in from 9 to 57 per cent. of cases. An average reduction of the normal carrying angle (Fig. 2) amounting to 10 degrees is

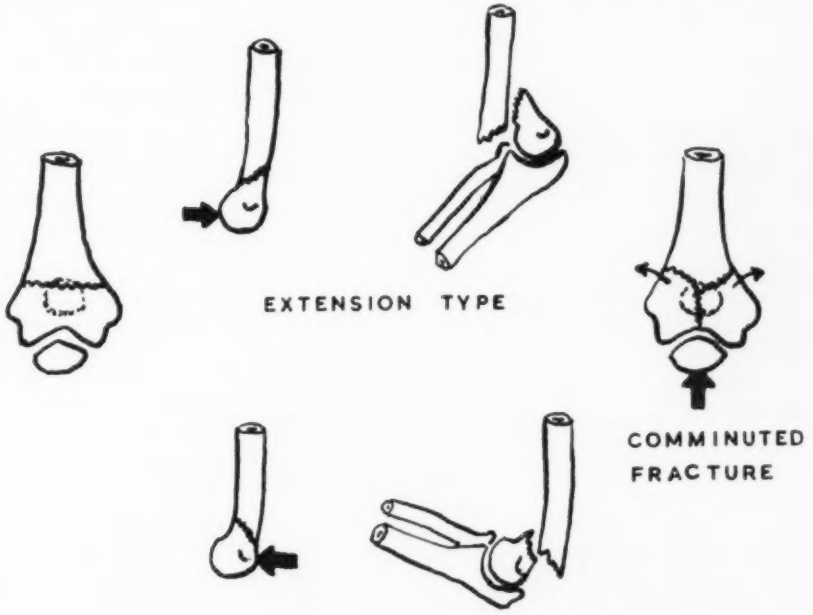

FIG. 1

Different types of supracondylar fractures of the humerus.

* Chief: Carl Semb, M.D.

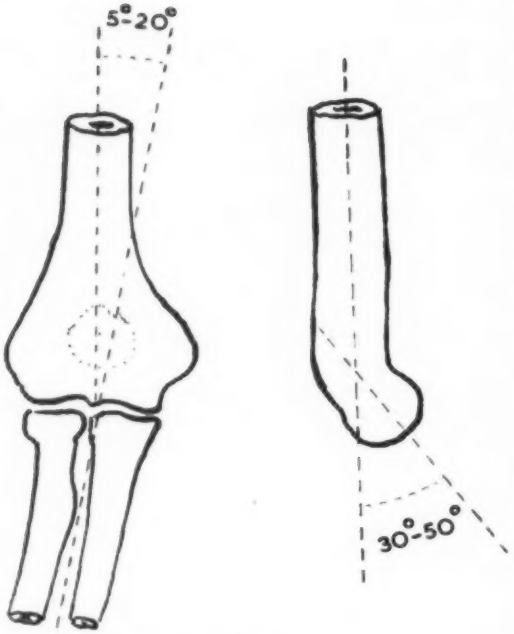

FIG. 2
Normal angles of the distal end of the humerus.

common in many series. This deformity is caused either by medial displacement or tilting of the distal fragment, or by inward rotation of this fragment in relation to the shaft of the humerus. The deformity is disfiguring and is usually accompanied by loss of function.

Cubitus valgus is much less common and is due to lateral displacement or tilting of the distal fragment.

Displacement backward will limit flexion, whereas displacement forward will limit extension of the elbow joint.

Three methods of treatment of these fractures are in common use: (1) manipulative reduction and fixation in a plaster cast with a "collar-and-cuff" sling; (2) open reduction and fixation; (3) sustained traction. Each method has its warm advocates. Böhler's method of treatment combines reduction and a plaster cast which incorporates constant traction.

FIG. 3
Schmerz hook-clip.

Traction was first recommended by the Norwegian surgeon Borchgrevink. He used a splint of his own construction; traction was applied by means of rubber tubing and adhesive straps. The method is still in use.

Later skeletal traction through the olecranon became the method of choice [2, 6, 10]. Several authors are opposed to this type of treatment because of the risk of infection [5, 7], or on account of unsatisfactory results [8]. Miller and his collaborators have achieved good results in a series of eighty-two cases in which traction through the olecranon was used as the only treatment.

In Department III of Ullevål Hospital skeletal traction through the olecranon has been the routine method of treatment for supracondylar fractures with displacement since 1935. Only a few of the cases have been treated by manipulative reduction and plaster fixation. These may be used as controls.

TECHNIQUE

Under general anaesthesia a small Schmerz hook-clip (Fig. 3) is inserted in the olecranon through two small skin incisions. Each spike of the hook-clip is hammered into the bone. The fracture is then reduced, preferably under the fluoroscope, and the arm is placed on an abduction splint of the type constructed by Semb (Fig. 4). Traction is maintained by means of rubber tubing.

If there is a tendency toward backward displacement of the distal fragment, this can be corrected by altering the traction in a more anterior direction. A pressure pad may be placed on the splint to prevent the arm from sliding forward (Fig. 4, insert *A*).

TABLE I

SUPRACONDYLAR FRACTURES OF HUMERUS TREATED

Type	Female	Male	Total
I		2	2
II	7	9	16
III	4	7	11
IV	9	14	23
Total	20	32	52

TABLE II

METHOD OF TREATMENT IN THE FOUR DIFFERENT TYPES OF FRACTURE

Treatment	Type I	Type II	Type III	Type IV	Total
Skeletal traction		6	9	17	32
Closed reduction and plaster		8	2	6	16
Dorsal plaster slab	2	2			4
Total	2	16	11	23	52

Increased flexion of the elbow joint will also counteract backward displacement of the distal fragment.

The fracture is repeatedly checked by x-rays. If the position is not fully satisfactory, corrections may be made easily. As a rule, minor displacements persisting after the primary reduction disappear with sustained traction without further adjustments.

Traction is continued for an average of twenty-one days. Then active movements and weight-carrying are instituted. Passive stretching and massage, on the other hand, are forbidden.

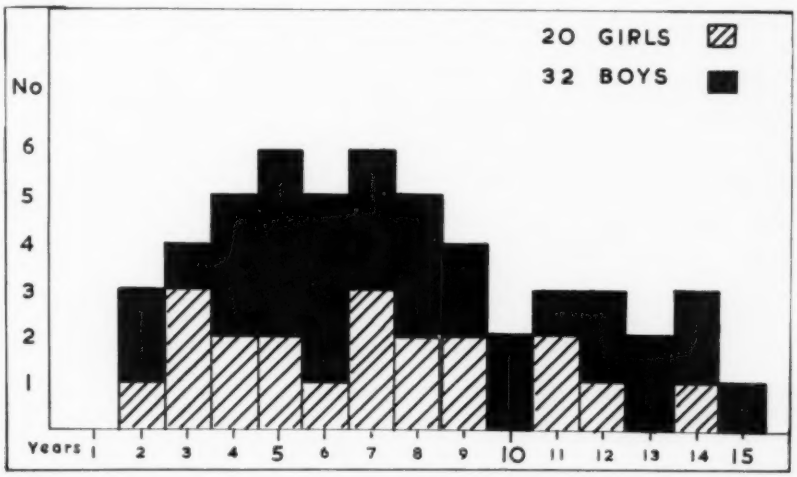

CHART I

Distribution by age and sex.

TABLE III

PRIMARY RESULTS

Treatment	I	I (II)	I (III)	II	II (III)	III	Total
Skeletal traction	5	10	3	10	3	1	32
Closed reduction and plaster	5	4	2	3	2	0	16
Dorsal plaster slab	2	0	0	2	0	0	4
Total	12	14	5	15	5	1	52

I: Ideal position. I (II): Slight lateral displacement. I (III): Slight degree of rotation. II: Lateral displacement. II (III): Lateral displacement and slight degree of rotation. III: Rotation.

AUTHOR'S SERIES

During the period from 1935 to 1947 inclusive, fifty-two supracondylar fractures of the humerus were treated. The age and sex incidence are shown in Chart I.

The fractures have been classified into four types according to the degree of displacement as suggested by Holmberg:

Type I. Fractures without displacement;

Type II. Fractures with lateral displacement;

Type III. Fractures with rotation, with or without lateral displacement;

Type IV. Fractures with complete displacement (no contact between the fragments).

Table I shows the material grouped according to this scheme. It will be seen that Type IV fractures were most common. There were only two flexion fractures and one comminuted Y-fracture. The remaining forty-nine were of the extension type, two of which were compound fractures.

The treatment employed in the different groups is shown in Table II. The two

TABLE IV

RESULTS AT FOLLOW-UP EXAMINATION

Treatment	Re-Examined	Unknown	Total
Skeletal traction	26	6*	32
Closed reduction and plaster	15	1	16
Dorsal plaster slab	3	1	4
Total	44	8	52

* Two of these stated by letter that their arms were in perfect condition.

TABLE V

CHANGES IN NORMAL CARRYING ANGLE

Treatment	No Change	Reduced Valgidity	Increased Valgidity	Total	Maximum (*Degrees*)	Mean (*Degrees*)
Skeletal traction	11	12	3	26	18	4.6
Closed reduction and plaster	5	10	0	15	24	7.6
Dorsal plaster slab	3	0	0	3	0	0
Total	19	22	3	44		

fractures of Type I and also two fractures of Type II were treated by a dorsal plaster slab and a "collar-and-cuff" sling only. Sixteen patients were treated by closed reduction and a plaster cast and thirty-two by skeletal traction. In six of the patients treated with traction, manipulative reduction and plaster-cast fixation were tried primarily, without success. In general, the fractures treated by traction were more severe than those treated in plaster.

The primary results—that is, the position of the fractures at the end of the treatment—are shown in Table III. Anatomical (I) or almost anatomical (I (II) and I (III)) reductions were achieved in eighteen (56.3 per cent.) of the patients treated with traction and in eleven (68.7 per cent.) of the patients treated with plaster. In two of the patients treated by plaster a late or secondary rotation displacement developed. This did not happen in any of those treated by traction.

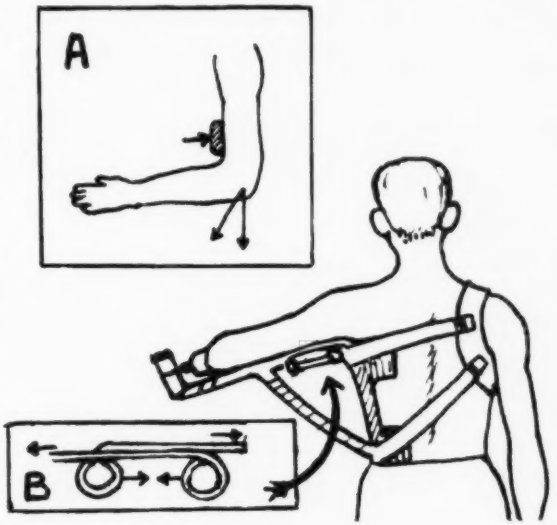

FIG. 4

Semb's abduction splint. Insert *A:* Pressure pad to prevent forward sliding of the arm. Insert *B:* Traction mechanism. Rubber tubing connecting the loops tends to lengthen the splint, thus producing traction on the attached Schmerz clip. (Reproduced by permission from the *Journal of the Oslo City Hospitals.*)

COMPLICATIONS

Among the patients treated by traction, there were two cases of paresis of the radial nerve and two of paresis of the median nerve. In one case, the only sign of nerve injury was an inability to extend the thumb, which was first discovered a few days after the treatment had been started. The other nerve injuries had been present before the treatment was instituted. In all four cases the paresis disappeared during the stay in the hospital. One patient had an incipient Volkmann's ischaemic contracture when admitted. The symptoms disappeared two days after reduction by the application of traction. In one case superficial infection at the site of the traction hook was recorded on the twentieth day. The traction was discontinued and the infection subsided without any special treatment.

TABLE VI

LIMITATION OF EXTENSION

Treatment	Not Present	Present	Total	Maximum (*Degrees*)	Mean (*Degrees*)
Skeletal traction	21	5	26	12	7.4
Closed reduction and plaster	13	2	15	15	9
Dorsal plaster slab	1	2	3	5	3.5
Total	35	9	44		

FIG. 5

Typical deformities following supracondylar fractures.

TABLE VII

LIMITATION OF FLEXION

Treatment	Not Present	Present	Total	Maximum (*Degrees*)	Mean (*Degrees*)
Skeletal traction	20	6	26	13	7.4
Closed reduction and plaster	11	4	15	10	6
Dorsal plaster slab	1	2	3	10	6.5
Total	32	12	44		

In the group treated by closed reduction and plaster, paresis or contracture has not been observed. In one compound fracture, skin necrosis developed which made skin-grafting necessary.

FOLLOW-UP STUDIES

Forty-four of the fifty-two patients have been re-examined clinically as well as roentgenographically from three to fifteen years after fracture. Two patients have answered

TABLE VIII

LIMITATION OF ROTATION

Treatment	Not Present (*No. of Cases*)	Present (*No. of Cases*)	Total (*No. of Cases*)	Maximum Limitation: Pronation (*Degrees*)	Maximum Limitation: Supination (*Degrees*)
Skeletal traction	25	1	26		5
Closed reduction and plaster	12	3	15	45*	45*
Dorsal plaster slab	3	0	3		
Total	40	4	44		

* Severe compound fracture. The other two patients had pronation limited by 5 and 10 degrees respectively.

FIG. 6-A

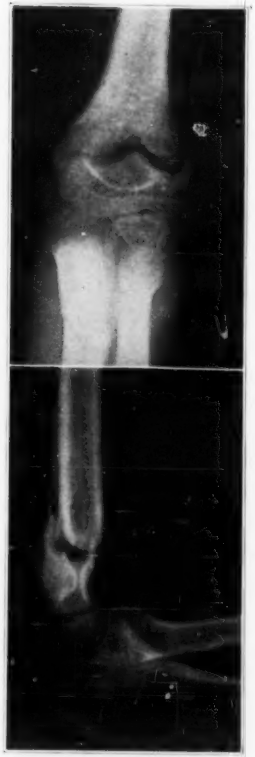

FIG. 6-B

FIG. 6-C

FIG. 6-D

Type IV fracture, left side, in a six-year-old boy. (Reproduced by permission from the *Journal of the Oslo City Hospitals.*)
Fig. 6-A: Before treatment. Fig. 6-B: After twenty-one days of traction the fracture had united in an almost perfect position.
Fig. 6-C: Eight years later: ideal result. Fig. 6-D: The uninjured right elbow.

FIG. 7-A

FIG. 7-B

FIG. 7-C

FIG. 7-D

Type III fracture, left side, in a seven-year-old boy. (Reproduced by permission from the *Journal of the Oslo City Hospitals.*)
Fig. 7-A: Before treatment. Fig. 7-B: During traction an almost ideal position was obtained.
Fig. 7-C: Five years later: good result. There were no complaints; there was a 15-degree reduction of the normal carrying angle; hyperextension was abolished (right: 10 degrees); function was otherwise normal. Fig. 7-D: The uninjured right elbow.

FIG. 8-A FIG. 8-B FIG. 8-C FIG. 8-D

Type III fracture, right side, in a five-year-old girl.

Fig. 8-A: Before treatment. Fig. 8-B: After twenty-two days of traction, the fracture united with slight lateral displacement.
Fig. 8-C: Eight years later: ideal result. Fig. 8-D: The uninjured left elbow.

FIG. 9-A

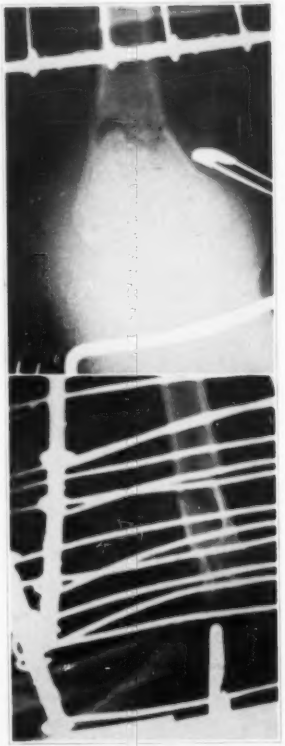

FIG. 9-B

FIG. 9-C

FIG. 9-D

Compound Type IV fracture, right side, in an eight-year-old boy. (Reproduced by permission from the *Journal of the Oslo City Hospitals.*)
Fig. 9-A: Before treatment. Fig. 9-B: After twenty-four days of traction, the fracture united in an ideal position.
Fig. 9-C: Five years later. The result was not satisfactory, but the patient had no complaints. There was a 16-degree reduction of the normal carrying angle, and hyperextension was abolished (left: 10 degrees); function was otherwise normal. Fig. 9-D: The uninjured left elbow.

FIG. 10-A

FIG. 10-B

FIG. 10-C

FIG. 10-D

Type II fracture in a four-year-old girl.

Fig. 10-A: Before treatment. Fig. 10-B: During treatment in a plaster cast the fracture united in an ideal position.

Fig. 10-C: Four years later the result was not satisfactory. Impaired growth of the trochlea caused a varus deformity. Rotation was slightly limited, but function was otherwise normal. Fig. 10-D: the uninjured left elbow.

FIG. 11-A FIG. 11-B

Follow-up examination of a girl who at eleven years of age had a Type III fracture which had been treated by skeletal traction for twenty-one days.

Fig. 11-A: Five years after injury the result was good and the patient had no complaints. There was a 6-degree reduction of the normal carrying angle and a 5-degree limitation of flexion; function was otherwise normal.

Fig. 11-B: The uninjured right elbow.

by letter that their arms are now in perfect condition. The remaining six patients could not be traced (Table IV).

Changes in the normal carrying angle (Table V) have been observed in twenty-five of the forty-four re-examined patients, three in a valgus direction and twenty-two in a varus direction. These changes occurred somewhat less frequently in the patients treated with traction than in those treated by closed reduction and plaster.

Limitation of extension (Table VI) has been recorded in nine patients. In the majority of the cases the limitation of extension consisted merely in reduced or abolished hyperextension. It is noteworthy that slight limitation of extension was found in two of the three patients whose fractures did not require reduction and who were treated merely with a dorsal plaster slab and a collar-and-cuff sling.

Limitation of flexion (Table VII) was found in twelve patients, and occurred somewhat more frequently in the patients treated by plaster than in those treated by traction. Two of the three patients treated by dorsal plaster slab also have limited flexion.

Limitation of rotation (Table VIII) was observed in four patients. One had had a compound fracture treated by traction and two had had simple fractures treated in plaster. These had but 5 to 10 degrees' loss of rotation. The fourth patient had had a compound fracture treated in plaster and showed severe limitation amounting to 90 degrees.

The final results in the patients who were re-examined after three to fifteen years are summarized in Table IX.

The criteria for an *ideal* result were: no complaints; changes in the normal carrying angle of less than 5 degrees; normal range of motion, or a reduction of flexion-extension or of rotation amounting to less than 10 degrees.

The result was classified as *good* when the changes in the normal carrying angle

TABLE IX

FINAL RESULTS

Type	Treatment	Ideal	Good	Not Satisfactory	Total
I	Plaster slab	2	0	0	2
II	Traction	3	2	0	5
	Closed reduction and plaster	5	1	2	8
	Plaster slab	0	1	0	1
III	Traction	5	2	0	7
	Closed reduction and plaster	1	1	0	2
IV	Traction	6	6	2	14
	Closed reduction and plaster	0	1	4	5
Total		22	14	8	44

TABLE X

PRIMARY RESULTS COMPARED WITH FINAL RESULTS

Primary Result		Final Results			
	Number of Patients	Ideal	Good	Not Satisfactory	Remarks
		Number of Patients			
I	9	6	1	2	Of the two whose results were not satisfactory, one had a compound fracture and both had impaired growth.
I (II)	12	7	3	2	Of the two whose results were not satisfactory, one had a refracture and both had impaired growth.
I (III)	5	1	4	0	The patient with the ideal result was three years old.
II	12	6	4	2	Of the two whose results were not satisfactory one had a compound fracture.
II (III)	5	2	2	1	The two with ideal results were four and seven years old respectively.
III	1	0	0	1	
Total	44	22	14	8	

ranged between 5 and 15 degrees, or when there was limitation of flexion-extension or of rotation amounting to 10 to 20 degrees.

The cases classified as *not satisfactory* presented changes surpassing these limits.

The eight patients classified as having not satisfactory results had arms fully fit for use, and none of them had any significant complaints. The reasons for classifying them in this group were: varus deformity in six cases, limitation of flexion-extension in one case, and limited rotation in one case.

Roentgenographic observations: The following three observations seem to be characteristic of healed supracondylar fractures of the humerus (Fig. 5).

TABLE XI

COMPARISON BETWEEN THE FINAL RESULTS OF OPERATIVE TREATMENT, TRACTION, AND MANIPULATIVE TREATMENT

Treatment	Results				Percentage of Satisfactory Results
	Ideal	Good	Unsatisfactory	Total	
Operation (Holmberg)	28	14	8	50	84
Traction (Dept. III, Ullevål Hospital)	14	10	2	26	92
Manipulation and plaster (Dept. III, Ullevål Hospital)	6	3	6	15	60

1. Periosteal bone formation, resulting in a broadening of the distal end of the humerus, especially on the lateral aspect. This was found in twenty-six of the forty-four patients (Figs. 6-A to 11-B).

2. An S-shaped deformity of the distal end of the humerus in the lateral view. This is due partly to increased bone formation posteriorly, and partly to an excavation of the humerus anteriorly, probably caused by pressure of the coronoid process. This deformity has been observed in half of the cases (Figs. 9-A to 9-D and 11-A and 11-B).

3. Perforation of the bony lamina in the bottom of the olecranon fossa. Although this is seen occasionally in normal elbows, in the author's series it has been recorded in nine patients, all on the side of the fracture.

Impaired growth of the trochlea has occurred in five cases, in two of them to a pronounced degree, with accompanying varus deformity (Figs. 10-A to 10-D), and in the remainder to an insignificant degree.

DISCUSSION

It will appear from the tables that closed reduction and plaster immobilization do not give as good results as treatment by traction, especially in cases with complete displacement (Type IV). In this group, ideal results were not obtained in any of the patients treated by closed reduction and plaster (Table IX). Furthermore it must be recalled that the group treated by traction included six patients who had been treated primarily by manipulative reduction and plaster without obtaining satisfactory reductions.

On comparing the primary with the final results (Table X), it will be seen that in the patients with healing in exact or almost exact position—I, I (II), I (III)—the final results are good. In the four cases where the results were not satisfactory, there were complicating factors. One was a compound fracture with severe soft-tissue damage. Another had a refracture two years later, treated elsewhere, and further details were not available. In the remaining two cases impaired growth of the trochlea humeri occurred.

Rotation (III) is a slightly more frequent cause of a poor result than lateral displacement (II). The three patients in whom ideal results were obtained in spite of rotation were all children, aged three, four, and seven years, respectively.

It is difficult to compare the results obtained in the present series with those of other authors, because the methods of classification of the fractures and of the results vary greatly. Holmberg published a series of 142 cases of supracondylar fracture of the humerus, 130 of which were re-examined. Of these, fifty were operated upon, and the remainder were treated by closed reduction and plaster or by the application of a plaster cast only. The grouping and classification in the present series are practically identical with those of Holmberg, and a comparison with his results may thus be justified. Holmberg adopted about the same indications for operation as we have followed for the application of traction.

It is, therefore, of special interest to compare these two groups (Table XI). It will be seen that the results of skeletal traction compare favorably with those of operative treatment and are considerably better than results from manipulation and plaster.

CONCLUSIONS

The present material indicates that the results of treatment of supracondylar fracture of the humerus by skeletal traction according to Semb's method are superior to those obtained by treatment with manipulative reduction and plaster. We may conclude that only fractures without displacement or those with backward displacement of slight degree should be treated by the application of a plaster cast, or by closed reduction and plaster fixation. In fractures with more extensive displacement, traction or operative treatment seems preferable.

The results of treatment by traction appear to be as good as those obtained by operative treatment. Since traction is a much simpler procedure than an operation and is fraught with less risk of complications, the open reduction should be resorted to only when it is obvious that the traction treatment will fail to give a satisfactory result. The present series indicates that this is rarely the case.

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BONE REGENERATION

An Experimental Study of Bone-Grafting Materials *†

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INTRODUCTION

There are two schools of thought today regarding bone regeneration. Proponents of the first theory hold that bone formation is governed by local humoral changes, including changes in circulation, hydrogen-ion concentration, and possibly the presence of a specific osteogenetic substance [2,7,17,18,19,27]. Claims for isolation of the latter have been made [20], and it has been named "osteogenin". However, others have not been able to confirm the presence of such a substance [13,23]. Supporters of the second theory believe that the osteoblasts derived from the primitive connective tissue, the endosteum, the periosteum, or the Haversian canals may survive transplantation and are capable of reproducing bone [3,8,12,21].

During 1948 a new substance was called to the attention of the author by Dr. Arthur Ward. The substance, a synthetic hydroxyapatite, was developed during the War by Elliott Barrett of the Mellon Institute, Pittsburgh, Pennsylvania, as a component of a granular adsorbent to replace bone char in sugar-refining. These basic calcium phosphate crystals behave physically and chemically like bone. They have the same x-ray diffraction pattern and almost the same chemical composition as natural bone [4].

An attempt was made to study the physiological properties of the compound and to compare it with fresh autogenous and frozen bone in filling skeletal defects created surgically in the long bones and iliac wings of dogs and burr holes in the crania of cats and monkeys. It was concluded from these experiments that the synthetic hydroxyapatite crystals could be replaced by new bone, but the crystals were not so effective as autogenous bone grafts in repairing the defects [25]. The problem as to whether their presence stimulated or induced new-bone formation remained unsolved.

In order to approach this problem, a second series of experiments was undertaken to determine suitable sites for studying ectopic bone formation. The results of these experiments confirmed the fact that autogenous grafts of cancellous bone can survive and grow when transplanted to skeletal musculature, to the ventricle of the brain, and to the anterior chamber of the eye in rats, guinea pigs, and rabbits.** The anterior chamber of the eye was selected for subsequent studies, since the fate of the grafts could be followed with a slit lamp and since the incidence of spontaneous new-bone formation resulting from trauma alone would be low.

The purpose of the present experiment was to determine: (1) what would be the response of the anterior chamber of the eye to injections of basic calcium phosphate apatite crystals; (2) whether or not bone grafts would survive freezing or lyophilizing and subsequently grow when implanted in the eye; and (3) if they did not survive, whether the dead transplants would "induce" bone formation in the recipient tissues.

METHOD

Transplants to the eye have been carried out in thirty-five guinea pigs and eighteen rats, as summarized in Table I.

* Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 20, 1951.

† This project was supported in part by Initiative 171 Funds from the State of Washington.

** These experiments were described in a paper read at the meeting of the Western Orthopedic Association, Portland, Oregon, October 4, 1950.

TABLE I

SUMMARY OF ANIMAL GROUPS

Type of Graft	Treatment before Implantation	Number of Animals
Basic Calcium Phosphate	None	6
Embryonic Femur	Frozen 24 hours	7
	Lyophilized 24 hours	6
	None	5
Fracture Callus	Frozen 24 hours	5
	Lyophilized 24 hours	6
	None	4
Adult Cortical and Cancellous Bone	Frozen 24 hours	5
	Lyophilized 24 hours	6
	None	3

The animals were divided into four groups: six guinea pigs in which basic calcium phosphate crystals were injected into the anterior chamber of the eye; eighteen adult rats in which the femora from eighteen-day rat embryos were implanted into the anterior chamber; fifteen guinea pigs in which were implanted fragments from the callus deposited around fractures of the tibia one week after fracture; and fourteen guinea pigs in which were implanted fragments of cortical and cancellous bone from the iliac crest. All groups except the first were further subdivided in the following fashion: In one group the grafts were frozen at −18 degrees centigrade for twenty-four hours prior to implantation; in the second the grafts were frozen in liquid carbon dioxide at −73 degrees centigrade and while frozen were desiccated under a vacuum of 0.1 millimeter of mercury for twenty-four hours before implantation; and in the last the grafts were implanted directly. Except for the

FIG. 1

Photomicrograph (× 95) of the synthetic hydroxyapatite six weeks after implantation in the anterior chamber of the eye of a guinea pig, showing the nature of the reaction of the recipient site.

basic calcium phosphate and the embryonic implants, all grafts were autogenous. The grafts were implanted by making a small nick in the sclerocorneal juncture and the bone (or callus) was inserted with a fine sterile wire as gently as possible. The basic calcium phosphate crystals were suspended in isotonic saline solution and injected with a fine hypodermic needle. To control the technique, a similar procedure was carried out on the opposite eye, except that no graft was implanted. In none of the controls in this series was spontaneous bone formation observed. Two of the eyes in which grafts were implanted became infected. In these no evidence of the grafts could be found at autopsy. A postoperative period of six weeks was selected for determining the results since, according to Wickstrom and Mosiman's experiments, six weeks after grafting appears to be the critical time for determining the viability of the graft.

RESULTS

Basic Calcium Phosphate

Of the six guinea pigs in which the basic calcium phosphate was injected into the anterior chamber, two showed, at the end of six weeks, no evidence of the crystals or cellular reaction histologically; two revealed a moderate cellular reaction but no crystals; and in two scattered crystals remained. The cellular reaction consisted predominantly of fibroblastic proliferation, small round-cell (plasma cell) infiltration, and the appearance of multinucleated giant cells (Fig. 1). In no instance was bone formation observed. In many respects the histological picture was similar to that seen around fragments of bone undergoing aseptic necrosis.

Embryonic Transplants

All of the embryonic femora subjected to freezing and all of those subjected to lyophilizing survived when transplanted to the anterior chamber. With re-establishment of

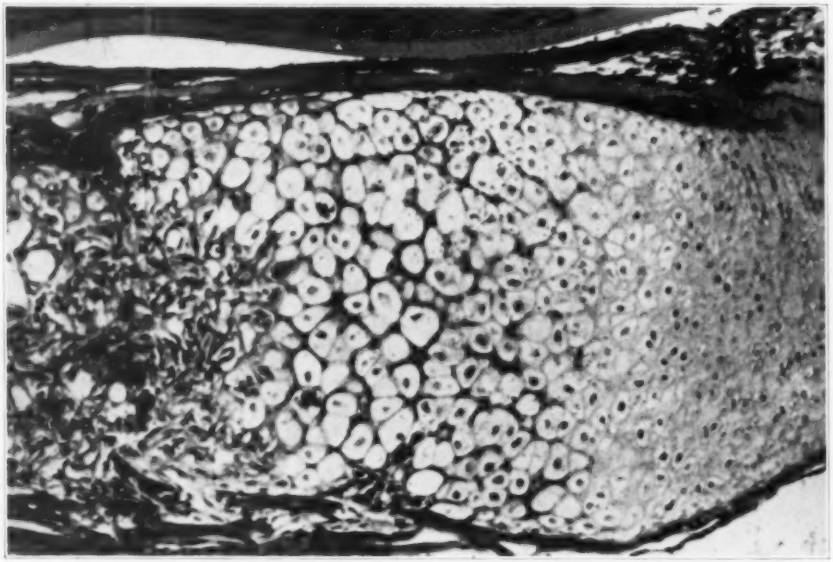

FIG. 2

Photomicrograph (× 28), six weeks after implantation, of the femur of an eighteen-day rat embryo subjected to freezing at −18 degrees centigrade for twenty-four hours and then implanted in the anterior chamber of the eye of an adult rat, showing survival of the graft and re-establishment of endochondral ossification.

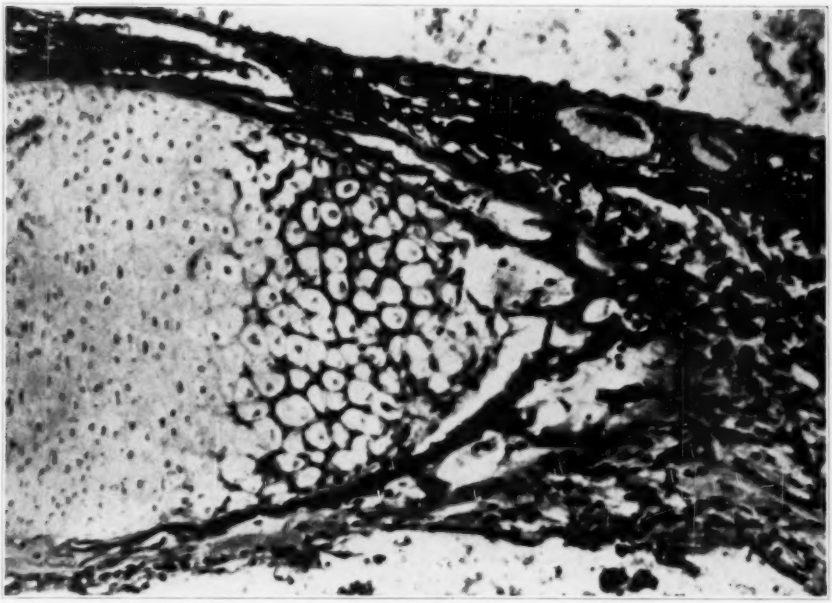

FIG. 3

Photomicrograph (× 28), six weeks after operation, of the femur of an eighteen-day rat embryo subjected to lyophilizing under a vacuum of 0.1 millimeter of mercury for twenty-four hours prior to implantation in the anterior chamber of the eye of an adult rat.

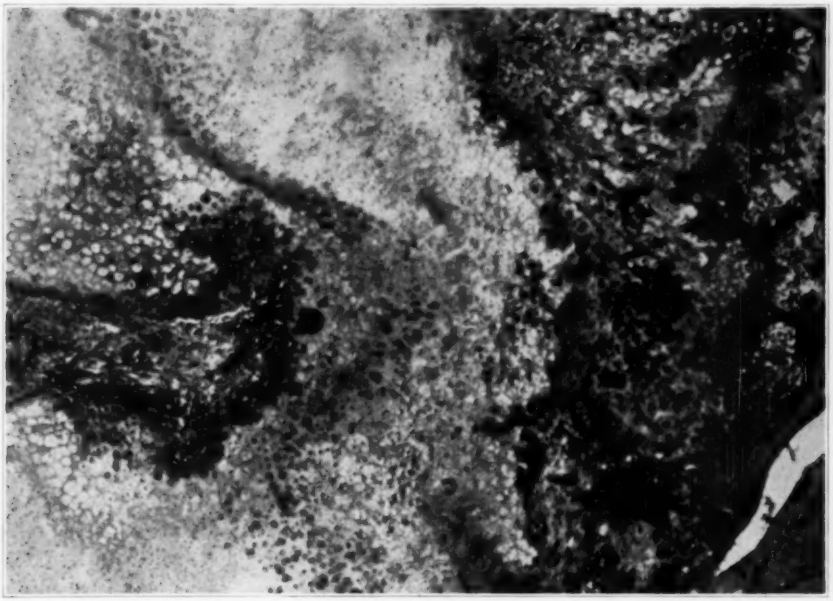

FIG. 4

Photomicrograph (× 28), six weeks after implantation, of the femur of an eighteen-day rat embryo implanted directly into the anterior chamber of an adult rat.

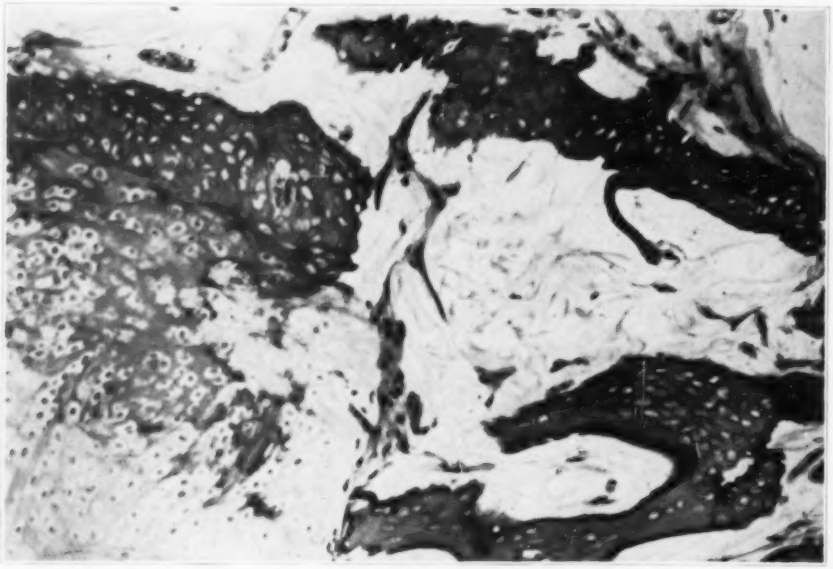

FIG. 5

Photomicrograph (× 28), six weeks after implantation, of an autogenous graft of fracture callus one week old, subjected to freezing at −18 degrees centigrade for twenty-four hours and then implanted in the eye of a guinea pig, showing survival of the callus but aseptic necrosis of the spicules of cortical bone.

circulation, the process of endochondral ossification continued, and bones of definitive shape could be recognized (Figs. 2 and 3). However, the growth observed following freezing or lyophilizing was not nearly as active as in those grafts which were transplanted directly without intervening treatment (Fig. 4).

Fracture Callus

Among the group of guinea pigs in which fracture callus was subjected to freezing prior to implantation, there was one instance of survival of the callus at the end of six weeks (Fig. 5). It is interesting to note that several chips of cancellous bone transplanted at the same time apparently underwent aseptic necrosis. Callus treated by lyophilizing prior to transplantation did not survive. On the other hand, in the group in which transplantation was carried out immediately, spicules of cortical bone were still viable after six weeks, and there was evidence of limited new-bone formation (Fig. 6).

Adult Cortical and Cancellous Bone

The autogenous grafts of mature cancellous and cortical bone subjected to freezing for twenty-four hours and those subjected to lyophilizing failed to survive. All showed evidence of aseptic necrosis at the end of the six-week period. Around some of the grafts there was a fibroblastic reaction similar to that seen around the basic calcium phosphate crystals. In some cases capillaries had invaded the Haversian canals, but there was no evidence of new-bone formation (Figs. 7 and 8). However, in the group in which transplantation was carried out without intervening treatment, the grafts did survive and in two instances there was histological evidence of limited new-bone formation (Fig. 9).

DISCUSSION

The reaction of the skeleton to implantation of basic calcium phosphate crystals resembled in many respects the reported reaction to implants of boiled bone [9,10,15] and os

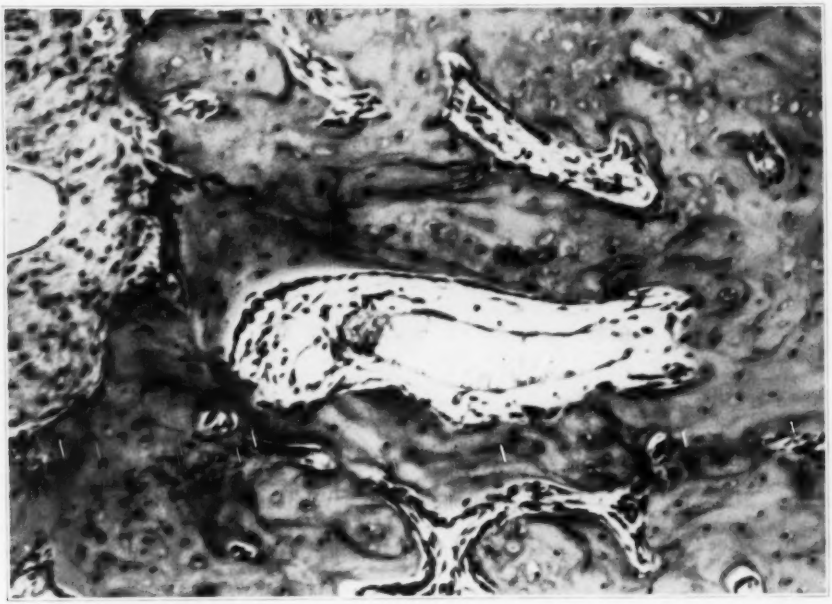

FIG. 6

Photomicrograph (× 28), six weeks after implantation, of an autogenous graft of cortical bone, from a fracture one week old, implanted in the eye of a guinea pig, showing survival of the bone.

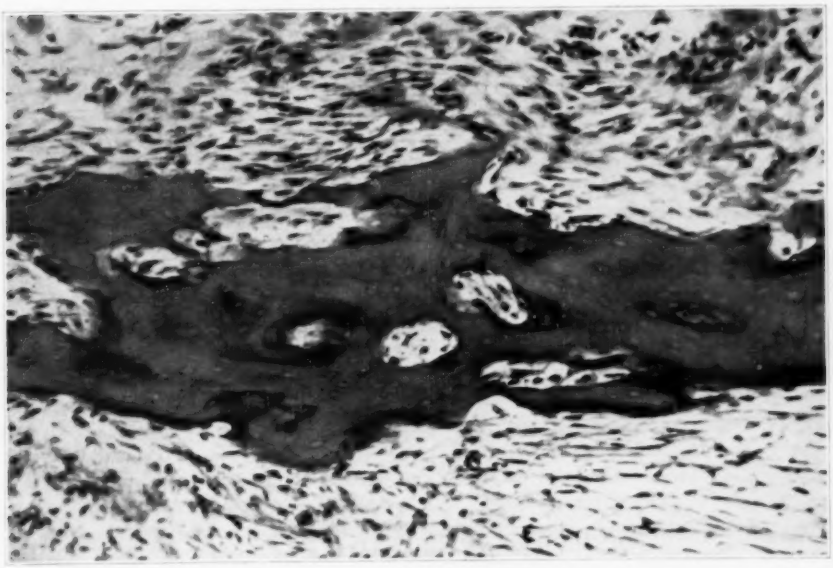

FIG. 7

Photomicrograph (× 28), six weeks after implantation, of an autogenous graft of adult cortical bone subjected to freezing at − 18 degrees centigrade for twenty-four hours and then transplanted to the anterior chamber, showing aseptic necrosis of the fragment.

FIG. 8

Photomicrograph (× 28), six weeks after implantation, of an autogenous graft of cancellous bone subjected to lyophilizing for twenty-four hours and then implanted in the anterior chamber, showing aseptic necrosis of the graft. The reaction of the recipient site is similar to that observed around the implanted synthetic apatite crystals.

purum [22]. Apparently these non-living substances act as scaffolds into which new bone can grow [5]. When the crystals were implanted in the anterior chamber of the eye, the reaction of the recipient site was in essence a foreign-body reaction. A similar reaction was observed around fragments of frozen or lyophilized bone which failed to survive. It would appear that a high local concentration of calcium phosphate, either alone or combined with the organic matrix of devitalized bone, is not capable of inducing the connective-tissue cells to undergo metaplasia into chondrocytes and osteocytes. This conclusion is in agreement with that reached by Huggins and his co-workers and by Urist [26].

While clinically there is a question regarding the fate of bone grafts [1,5,11,24], the experiment here described, as well as the preliminary studies, confirm the findings of Klinkerfuss, Urist and McLean [27], Wickstrom and Mosiman, and others, that homogenous embryonic bone and autogenous grafts of fracture callus and adult cancellous and cortical bone can survive in a suitable ectopic site. Since the survival of the cells is directly dependent on diffusion of tissue fluids through the ground substance, both the nature of the ground substance and the thickness of the graft should be important. However, this is a problem for future study.

The preceding experiment also demonstrates that embryonic bone will survive freezing (or lyophilizing) for limited periods of time and subsequently grow when transplanted into the anterior chamber of the eye. According to our results, however, grafts of fracture callus and mature cancellous and cortical bone are less able to withstand such treatment. Furthermore, it should be emphasized that freezing or lyophilizing the embryonic transplants delayed subsequent growth as compared with transplants which had had no prior treatment. These results can be explained if living cells are responsible for the propagation of bone. On the other hand, such results are difficult to explain on the basis of a specific chemical osteogenetic organizer.

The factors responsible for metaplasia of the primitive connective-tissue cells remain

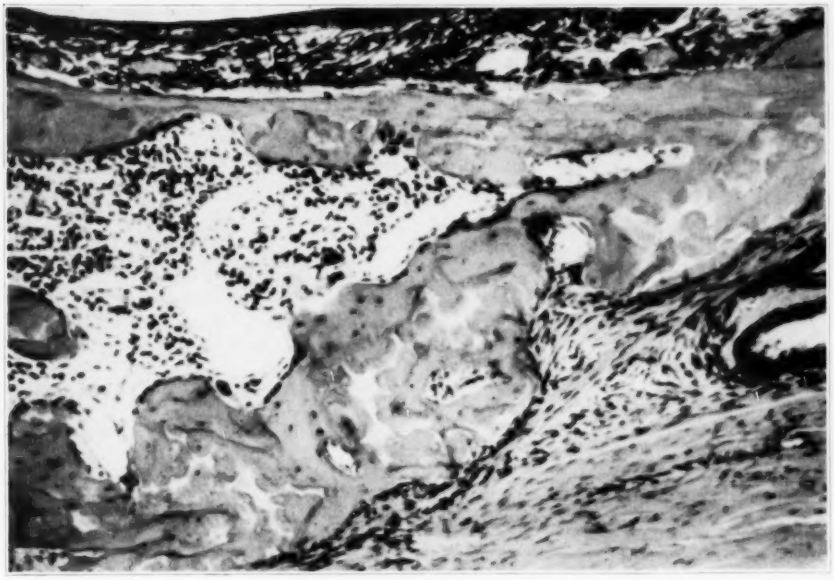

FIG. 9

Photomicrograph (× 28) of an autogenous graft of cancellous and cortical bone implanted in the eye without intervening treatment; six weeks after implantation survival of the graft is evident.

obscure. Genetic patterns, trauma with or without necrosis, and an autocatalytic reaction to living chondroblasts or osteoblasts are some of the possibilities awaiting future investigation.

SUMMARY

Studies of histological sections of implants in the anterior chamber of the eye in thirty-five guinea pigs and eighteen rats, made six weeks after implantation, revealed the following:

1. Injection of synthetic basic calcium phosphate apatite crystals resembling the inorganic crystals from natural bone resulted in a foreign-body reaction in four out of six guinea pigs.

2. Grafts of the femora of eighteen-day rat embryos frozen at −18 degrees centigrade for twenty-four hours and then transplanted to the anterior chamber of the eye of adult rats survived in seven out of seven cases. Endochondral ossification was re-established. Similar grafts lyophilized under a vacuum of 0.1 millimeter of mercury for twenty-four hours also survived in six out of six instances. Embryonic femora transplanted directly without intervening treatment not only survived in five out of five animals, with re-establishment of endochondral ossification, but growth was much more active than in either of the two preceding groups.

3. Autogenous implants of fracture callus frozen at −18 degrees centigrade for twenty-four hours and implanted one week after fracture, survived in the anterior chamber of the eye for six weeks in one out of five guinea pigs. Fracture callus treated by lyophilizing for twenty-four hours prior to implantation failed to survive in six out of six cases. Fracture callus and spicules of adult bone transplanted without intervening treatment survived in four out of four instances.

4. Autogenous grafts of adult cancellous and cortical bone treated by freezing in five

guinea pigs and by lyophilizing in six animals failed to survive in all instances. However, grafts transplanted directly survived in three out of three guinea pigs.

These studies, therefore, confirm the fact that homogenous grafts of embryonic bone and autogenous grafts of fracture callus and adult cancellous and cortical bone can survive and proliferate in a suitable ectopic site. Furthermore, embryonic bone frozen at −18 degrees centigrade or lyophilized under a vacuum of 0.1 millimeter of mercury for twenty-four hours will survive and grow when implanted in an ectopic location. Fracture callus and adult cancellous and cortical bone are less able to survive in an ectopic site following freezing or lyophilizing.

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ILIOPSOAS TRANSFER FOR WEAKNESS OF THE HIP ABDUCTORS

A PRELIMINARY REPORT*

BY W. T. MUSTARD, M.D., TORONTO, ONTARIO, CANADA

From The Hospital for Sick Children, Toronto

Paralysis or weakness of the hip abductor muscles allows the pelvis to tilt to the opposite side when the body weight is borne on the affected limb. A compensatory lurch of the body to the affected side in order to regain balance produces a characteristic gait. Accompanying this fatiguing and disfiguring limp is an external rotational deformity of the extremity. Several muscles have been transferred in an attempt to restore pelvic stability. It has been the author's experience that none of the muscles selected, either alone or in combination, is capable of replacing the stabilizing power of the hip abductors.

The author became interested in the iliopsoas for a number of reasons. The iliopsoas, lying as it does on the inside of the pelvis, has the necessary muscle bulk to equal the hip abductor muscles, and the short fibers of the iliacus suggest that it would add to the power of stabilization rather than increase the range of motion. The innervation of the muscle is such that, in poliomyelitis, its anterior horn cells are often spared when those of the hip abductors are involved.

Anatomically, its origin and insertion are very similar to those of the hip abductor muscles, except, of course, that the situation is reversed. The origin of the iliacus inside the pelvis is almost identical with the origin of the abductors outside the pelvis; the lesser trochanter is about the same distance from the iliac crest as is the greater trochanter. When the iliopsoas is tested electromyographically, with a needle electrode in the iliacus, muscle contractions are recorded if one bears weight on the side being tested. This result is indicative that the iliopsoas is a hip stabilizer.

After considering these factors, the author attempted a surgical approach on a cadaver. It was demonstrated that through an anterolateral incision, such as the one

*Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 23, 1951.

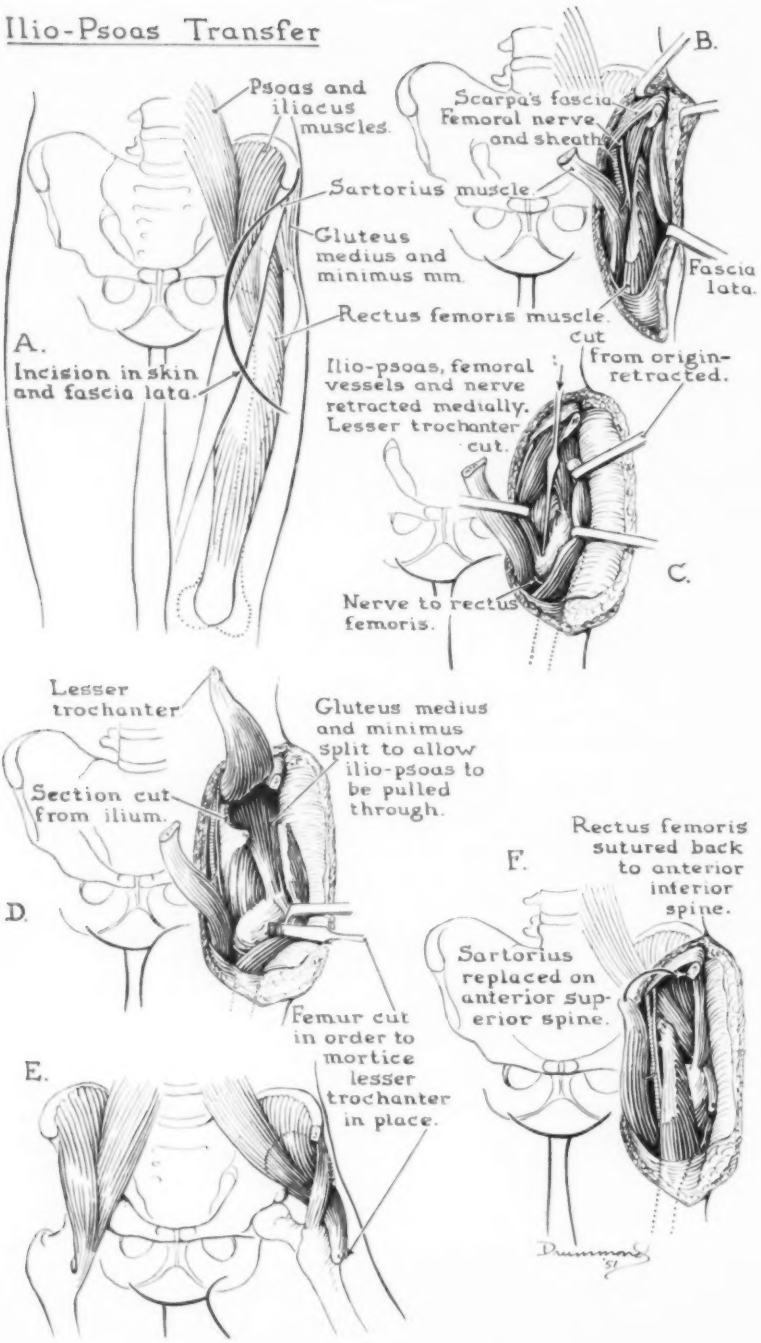
Ilio-Psoas Transfer
Psoas and iliacus muscles.
A.
Incision in skin and fascia lata.
B.
Scarpa's fascia.
Femoral nerve and sheath.
Sartorius muscle.
Gluteus medius and minimus mm.
Fascia lata.
Rectus femoris muscle.
cut
from origin-retracted.
Ilio-psoas, femoral vessels and nerve retracted medially.
Lesser trochanter cut.
C.
Nerve to rectus femoris.
Lesser trochanter
Gluteus medius and minimus split to allow ilio-psoas to be pulled through.
Section cut from ilium.
D.
Femur cut in order to mortice lesser trochanter in place.
E.
F.
Rectus femoris sutured back to anterior inferior spine.
Sartorius replaced on anterior superior spine.
Drummond '51

FIG. 1

FIG. 2-A

FIG. 2-C

FIG. 2-B

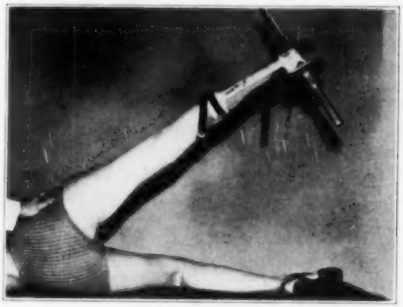

FIG. 3-A

Fig. 2-A: Abduction rated "poor" prior to iliopsoas transfer.
Fig. 2-B: Abduction rated "good" two months after iliopsoas transfer.
Fig. 2-C: Flexion to a right angle two months following iliopsoas transfer.
Fig. 3-A: Abduction rated "nil" prior to transfer. Eighteen months after operation, abduction was rated "good plus".
Fig. 3-B: Flexion to a right angle eighteen months after iliopsoas transfer.

FIG. 3-B

employed by Smith-Petersen, the iliopsoas (with its insertion into the lesser trochanter) could be transferred laterally to the shaft of the femur below the greater trochanter. The muscle belly is made to pass through a notch cut in the wing of the ilium between the anterior superior and anterior inferior spines and fulfills the usual requirements of a tendon transfer. The steps in this surgical procedure are illustrated by the drawings (Fig. 1).

In the selection of patients for this operation, there are two major requirements: The patient must have a good or normal glutaeus maximus to assist in pelvic stability, and he must have a normal sartorius to act as a hip flexor. A good or normal rectus femoris aids somewhat in hip flexion.

During the past two years this operation has been employed in twelve patients. Two underwent the operation too recently for appraisal; two patients were poorly selected (in one of these the glutaeus maximus was rated as "nil" and in the other it was rated as poor), and in one patient the muscle was not put under enough tension at the time of its transfer. In the remaining seven patients the hip stability has been improved; and, in one patient, the result can be considered excellent.

In conclusion it may be stated that transferring the iliopsoas through the pelvis restores abductor power to the hip. Flexion is possible to a right angle if a normal sartorius is present. If the usual rules of tendon transfer are observed, patients are improved both subjectively and objectively; and, if good or better power develops in the transferred muscle, the Trendelenburg gait is considerably lessened.

DISCUSSION

Dr. Edward L. Compere, Chicago, Illinois: In so far as I have been able to determine, this is a completely new and original procedure. For that reason, I cannot speak about it from the standpoint of having had any experience whatsoever with it. Among procedures which have been used and are recommended for the purpose of restoring some function to hip abductor muscles paralyzed by poliomyelitis are those of Lange, Ober, Hipps, and Irwin. In no instance that I know of has a muscle which is as strong or as immediately available as a good iliopsoas been used in any of these earlier procedures.

Dr. Mustard is certainly to be congratulated upon the originality which he has shown in planning, and the courage which he has demonstrated in executing, this most ingenious and, I believe, practical procedure. He has been extremely modest in his claims with regard to what may be accomplished by the procedure. Among other things, he has emphasized the fact that in at least two patients the selection of the patient was not a wise one because of a weakness or absence of a glutaeus maximus. He has also pointed out that it is important for the success of this operation that there be a strong sartorius. I believe that we might also add that, for any procedure to restore stability to the hip where the power of abductor muscles has been lost, we do need strong enough abdominal muscles to stabilize in position the pelvis with relationship to the thorax. I would certainly wish to establish their presence before undertaking any such procedure. For those patients who have less than enough power of the appropriate muscles to make a muscle-transplant operation advisable, stabilization of the hip by arthrodesis should be considered.

I wish to thank Dr. Mustard for bringing to our attention another useful procedure for the restoration of function in those patients who have been the victims of poliomyelitis.

Dr. Leo Mayer, New York City: This is a most ingenious operation and I am delighted to have heard it reported. There are two points which I wish Dr. Mustard would explain more clearly, for the patients reported obviously were not injured in any way. First, how is one to avoid injury to the anterior crural nerve and how is one to retract the nerve so as to get it out of the path of the muscle which he transplants? Second, just how is one to construct the notch in the ilium? How large must that notch be and exactly where must it be placed? Does Dr. Mustard place any protection over the rough margin of the bone so as to facilitate the gliding of the muscle?

Dr. M. Beckett Howorth, New York City: I would like to ask Dr. Mustard two questions:

1. Has he considered separating the iliacus from the psoas and transplanting only the psoas so as to preserve a greater portion of the hip flexor power?

2. Would it be desirable to transplant the tendon of the rectus femoris, the long tendon at least, to the anterior superior spine, in order to increase its flexor power?

Dr. George J. Garceau, Indianapolis, Indiana: I rise to answer Dr. Howorth's question rather than to discuss Dr. Mustard's paper, because I have had no experience with iliopsoas-muscle transplant. We have transplanted the iliacus in two patients. It has been long enough since the first patient was operated upon to evaluate the result; it is very good. The operation was performed through an exposure similar to that described by Dr. Mustard, and the femoral nerve is easily exposed and protected.

Dr. Mustard (closing): I wish to thank the discussors very much for their kindness.

In answer to Dr. Compere's question, there must be good abdominal muscles present.

Answering Dr. Mayer's question about the femoral nerve, let me say that it is not difficult to get the nerve out of the way if one retracts it with the vascular bundle, being careful to preserve the nerves of the sartorius which come out rather high.

In regard to Dr. Howorth's question concerning the iliacus as opposed to the iliopsoas, and also in regard to Dr. Garceau's very interesting comment on his case, I have considered separating the iliacus from the tendon of the psoas. When I had dissected it out from the cadaver in the anatomy laboratory, I found that the insertion of the iliacus muscle is a muscular insertion. Therefore, I found it unwise to use it as a transfer. Rather I would take the iliopsoas tendon and lesser trochanter with as much of the insertion of the iliacus as possible (the iliacus insertion not only goes somewhat into the lesser trochanter but carries on down the shaft of the linea aspera which is cut off distal to the tendon) and get the whole iliacus with the psoas (it seems to be one structure) and deliver it back into the wound.

COMMINUTED FRACTURES OF THE DISTAL END OF THE RADIUS TREATED BY ULNAR PINNING

BY ANTHONY F. DEPALMA, M.D., PHILADELPHIA, PENNSYLVANIA

From the Department of Orthopaedic Surgery, Jefferson Medical College Hospital, Philadelphia

Despite the fact that fractures of the distal end of the radius are by far the most common fractures encountered, there is a paucity of end-result studies of this lesion to determine whether or not present methods of management are adequate. In spite of this lack of critical assessment, it is common knowledge that loss of length of the radius, diminution or obliteration of the radial tilt of the articular surface of the radius, and supination of the distal segment of the radius are the three factors chiefly responsible for poor cosmetic and functional results. This knowledge prompted renewed interest in the mechanism of the production and management of this lesion. The method of treatment recorded in this article was evolved from this study but was first suggested to the author by Henry Briggs.

Recently Gartland and Werley conducted a survey of Colles' fractures treated at the

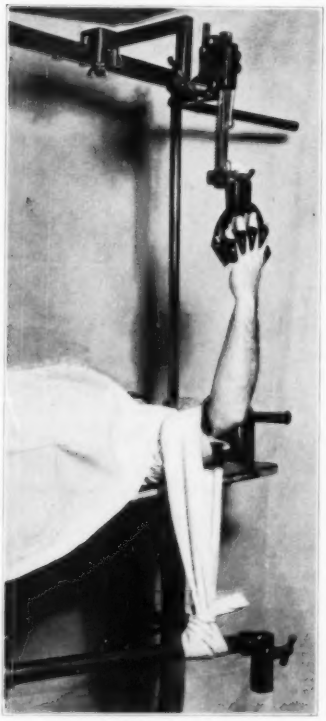

FIG. 1

FIG. 2

Fig. 1: Position of the arms; the Weinberger finger traction apparatus has been attached to apply vertical traction on the wrist joint.

Fig. 2: Lateral and radial pressure is applied to the volar aspect of the forearm in an attempt to restore the normal volar tilt of the radius. This position is maintained while the wire is inserted obliquely through the ulna and radius.

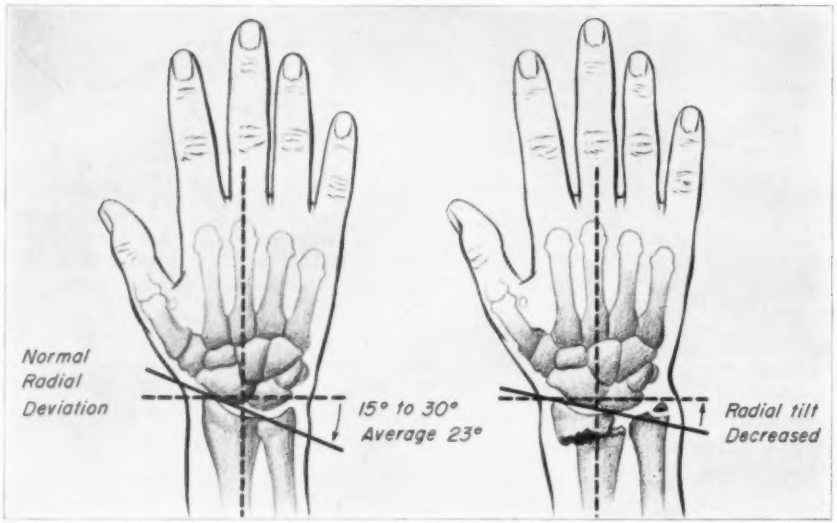

FIG. 3-A FIG. 3-B

Fig. 3-A: Normal tilt of articular surface of the radius ranges from 15 to 30 degrees.
Fig. 3-B: Reduction of the radial tilt in a Colles' fracture.

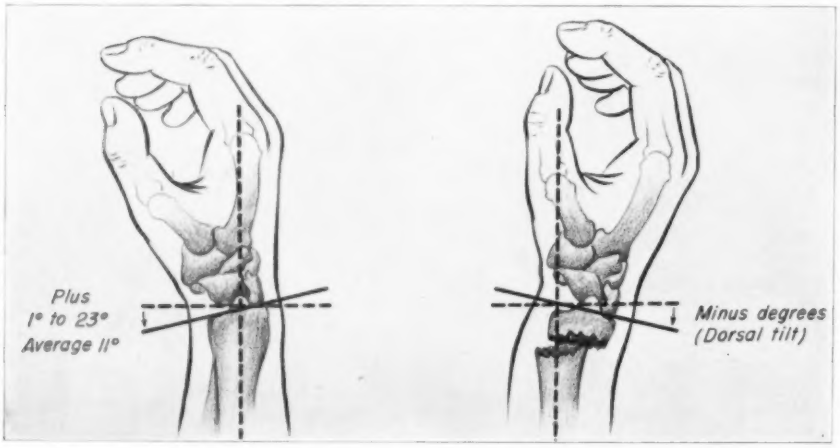

FIG. 3-C FIG. 3-D

Fig. 3-C: Normal volar tilt of the radius ranges from 1 to 23 degrees.
Fig. 3-D: Dorsal tilt in a Colles' fracture, expressed in minus degrees.

Jefferson Medical College Hospital. Their study uncovered several significant facts which substantiate the belief of many orthopaedic surgeons that present methods of treatment should be challenged and more adequate methods found.

These observers studied sixty Colles' fractures; the follow-up periods on these cases ranged from twelve to forty-six months. In all instances the fractures were reduced by manipulation and the wrist was placed in a position of palmar flexion and ulnar deviation. Immobilization was maintained by volar and dorsal plaster splints held in position with a circular gauze bandage. The splint extended from just proximal to the metacarpal heads to

TABLE I (Group A)

FUNCTIONAL RESULTS

	Cases	Per cent. of Series
Excellent	13	22
Good	28	47
Fair	17	28
Poor	2	3

TABLE II (Group B)

FUNCTIONAL RESULTS

	Cases	Per cent. of Series
Excellent	16	57.1
Good	7	25.0
Fair	5	17.8
Poor	0	0

the bend of the elbow. After an average period of two weeks the splints were removed, the wrist was brought to a neutral position, and new plaster splints were applied. The average period of fixation in plaster was six weeks.

This survey disclosed unequivocally that a residual dorsal tilt of the radius of more than five degrees and loss of the inward tilt of the articular surface of the radius exceeding three millimeters were alterations concomitant with poor function. In addition to these factors, if the supination twist (when present) of the distal radial fragment sustained at the time of the injury is not corrected, it further reduces the inward tilt of the articular surface of the radius. In the series reviewed 31.7 per cent. of the patients had an unsatisfactory result. The greater majority of the patients in this unsatisfactory group revealed varying degrees of comminution of the articular surface of the radius at the time of the injury. The incidence, as determined by roentgenogram, of traumatic arthritis in fractures with comminution was 24.5 per cent. From these observations it was concluded that in those patients with unsatisfactory results some or all of the components of reduction (the restoration of the normal volar tilt, the inward tilt of the articular surface of the radius, the normal length of the radius, and obliteration of the supination twist of the distal end of the radius) were lost between the time of reduction and the final healing stage of the fractured fragments. Lack of adequate immobilization was believed to be the most important factor responsible for the residual deformities and the poor functional results.

In the light of these observations it becomes apparent that two factors govern the final functional capacity of the wrist: complete restoration of anatomical alignment of all fragments and maintenance of this position until healing is complete. This study further disclosed that plaster fixation for an average period of six weeks does not preclude redisplacement of the fragments.

ANATOMICAL OBSERVATIONS

Study of the anatomy of the wrist joint in anatomical specimens revealed that the distal end of the radius and ulna are encased in a continuous broad fibrous envelope comprising the volar and dorsal radiocarpal ligaments and the radial and ulnar collateral

TABLE III (Group B)

DORSAL TILT OF THE ARTICULAR SURFACE OF THE RADIUS

End Result	Before Reduction Group Average (*Degrees*)	After Reduction Group Average (*Degrees*)	Final Position Group Average. (*Degrees*)
Excellent	−9.7	−7.1	−3.5
Good	−19	−5.3	−2.3
Fair	−19	−6	−8
Poor	0	0	0

FIG. 4-A

Case L. A. Showing a typical comminuted fracture of the distal end of the radius with loss of the radial tilt, a severe dorsal tilt, and supination twist of the distal radial fragments.

ligaments. The integrity of the radio-ulnar joint is chiefly maintained by the articular disc, a triangular structure beneath the head of the ulna which binds the distal end of the ulna and radius firmly together.

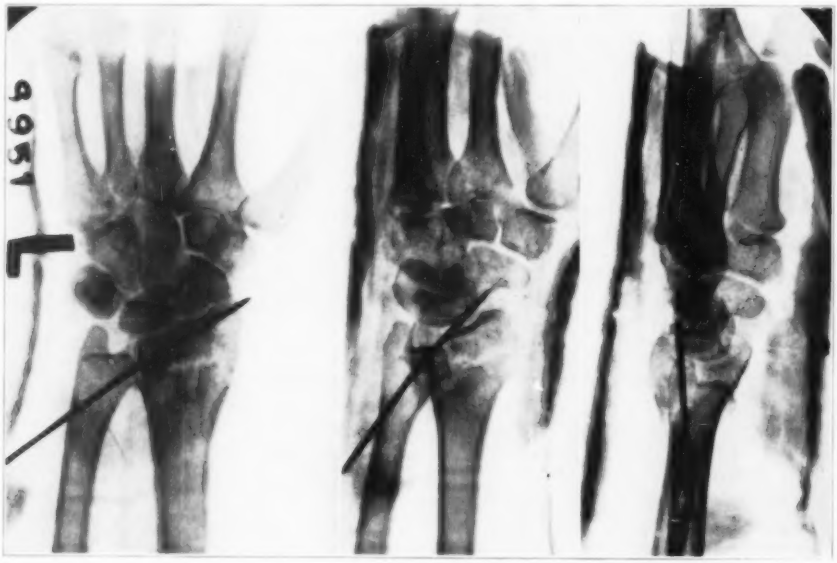

FIG. 4-B

Roentgenograms made immediately after reduction, showing restoration of all components of the fracture.

TABLE IV (Group A)

DORSAL TILT OF ARTICULAR SURFACE OF THE RADIUS

End Result	Before Reduction Group Average (*Degrees*)	After Reduction Group Average (*Degrees*)	Final Position Group Average (*Degrees*)
Excellent	−15	+6	0
Good	−21	+2	−2
Fair	−20	+4	−5

TABLE V (Group B)

RADIAL DEVIATION

End Result	Before Reduction Group Average (*Degrees*)	After Reduction Group Average (*Degrees*)	Final Position Group Average (*Degrees*)
Excellent	18.6	23.1	20.7
Good	9	23	20
Fair	11	23	21
Poor	0	0	0

Comminuted fractures of the distal end of the radius were produced in cadaver specimens. Dissection of the fractured regions revealed that, in spite of the severity of the comminution, the ligamentous structures described remained essentially intact. Furthermore, it was noted that, even in the most severely comminuted types of fractures, the outer end of the radius was spared in most instances and remained as a relatively large segment. Anatomical repositioning of the fractured fragments and complete obliteration of the supination twist of the distal fragments were readily achieved in these experimental specimens by straight traction on the hand, with the hand and forearm in full supination. This method, however, did not in all instances restore the normal volar tilt of the radius which in the normal ranges from 1 to 21 degrees, with an average of 11 degrees. It was further observed that if the outer segment of the radius could be maintained in the corrected position, the remaining fragments would be pulled and held in position by the volar and dorsal radiocarpal ligaments.

FIG. 4-C

End result twenty-four months later.

MATERIAL AND METHODS

The observations made on anatomical specimens formed the basis for this investigation of clinical results. Not all types of Colles' fractures were treated by the method described in this article. The method was reserved for those patients with comminution of the articular surface of the radius comparable to Groups II and III described by Gartland and Werley.

FIG. 5-A

Fig. 5-A: Case L. T. Severe comminution of the distal end of the radius and an oblique fracture of the ulna, with extreme deformity of the wrist.

Fig. 5-B: Postreduction roentgenograms. Because of the unstable ulnar fragments two transfixation wires were used.

These workers placed their cases in three categories: Group I, simple Colles' fractures with no involvement of the articular surface of the radius (seven cases, 12 per cent.); Group II, comminuted Colles fractures with fractures of the articular surface of the radius but with no displacement (twenty-seven cases, 45 per cent.); Group III, comminuted Colles' fractures with fractures of the articular surface of the radius and displacement of the fragments (twenty-six cases, 43 per cent.).

Up to the present time, thirty-nine patients have been treated by the method to be described. Of these, twenty-eight cases have a follow-up period ranging from twelve to thirty-six months; these cases were used in this study. The ages ranged from thirty-six to sixty-nine years; there were eighteen females and ten males, the right wrist was involved in seventeen cases and the left in eleven. It was interesting to note the higher incidence of this lesion in females (64.2 per cent.).

Fig. 5-B

Essentially, the method consists in reduction of the fracture by traction and molding of the fragments. The corrected position is maintained by means of a threaded wire passing through the ulna to the most distal radial fragment, which invariably includes the styloid process of the radius.

The procedure is carried out under general anaesthesia; we prefer pentothal sodium. The patient is placed on a fracture table in the supine position and the affected extremity is suspended from an overhead bar by means of a Weinberger finger-traction apparatus. Before traction is applied, the arm is placed in a position of 90 degrees to the trunk and the elbow is flexed 90 degrees, with the hand and forearm in full supination. The arm in the region of the elbow is bound down firmly to a lower bar by a four-inch muslin bandage; a piece of felt, one-half inch thick, is placed under the muslin bandage to protect the skin. Straight traction is then made on the wrist by means of the Weinberger finger-traction apparatus (Fig. 1). After the length of the radius has been restored, the fragments are

TABLE VI (Group A)

RADIAL DEVIATION

End Result	Before Reduction Group Average (*Degrees*)	After Reduction Group Average (*Degrees*)	Follow-up Group Average (*Degrees*)
Excellent	20	22	20
Good	16	18	16
Fair	19	21	19

molded and squeezed into place by the surgeon's thumbs and index fingers; finally an assistant applies and maintains outward pressure on the volar aspect of the forearm, thereby restoring the volar tilt of the distal radial fragments. While outward pressure is maintained on the volar aspect of the forearm, a threaded wire measuring three thirty-seconds of an inch is passed through the ulna and radius, entering the ulna at a point one and one-half to one and three-quarter inches from the tip of the ulnar styloid process and directed obliquely upward and outward so that it engages the radial styloid fragment (Fig. 2). The wire is cut just below the level of the skin. A circular plaster cast is applied which extends from behind the heads of the metacarpal bones on the dorsal surface and just behind the distal flexion crease in the palm to the bend of the elbow. After the plaster has hardened, the arm is removed from the traction apparatus and placed in a sling. Finger, elbow, and shoulder movements are started immediately on a regulated schedule. The cast and wire are removed at the end of eight weeks and physical therapy is started to obtain optimum function of the wrist, hand, and fingers.

FIG. 5-C

End result eighteen months later. This patient rated an excellent result.

For the benefit of those who may think this method of treatment worthy of trial, some of the pitfalls which we encountered should be mentioned. It is essential that a threaded wire be used in all instances. In our earlier cases unthreaded wires were employed and the ends were left protruding from the skin about one-half inch. The exposed end of the wire was incorporated in plaster in an attempt to prevent migration of the wire. In spite of this precaution, several of the wires migrated and protruded from the tip of the

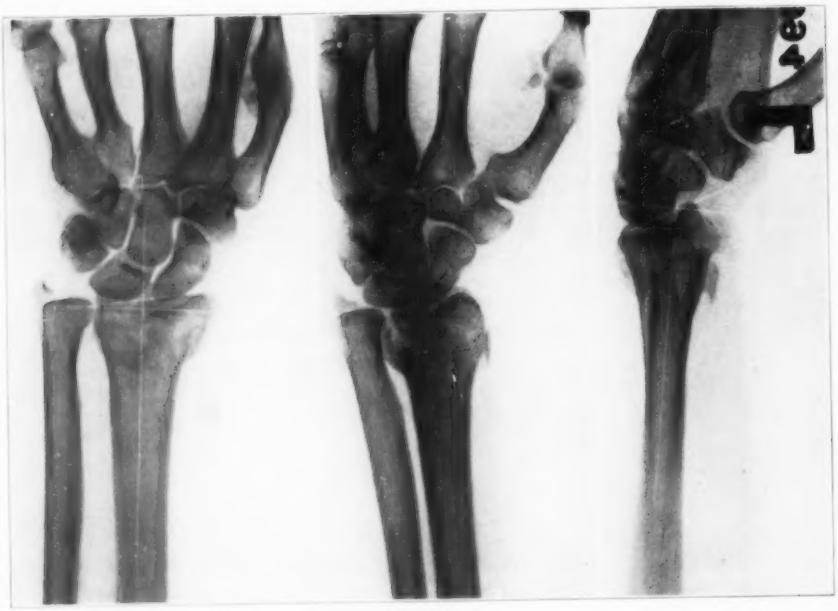

FIG. 6-A

Case L. H. Typical severely comminuted fracture of the distal end of the radius and a fracture through the base of the styloid process. Note reduction in deviation of the radial articular surface and severe dorsal tilt.

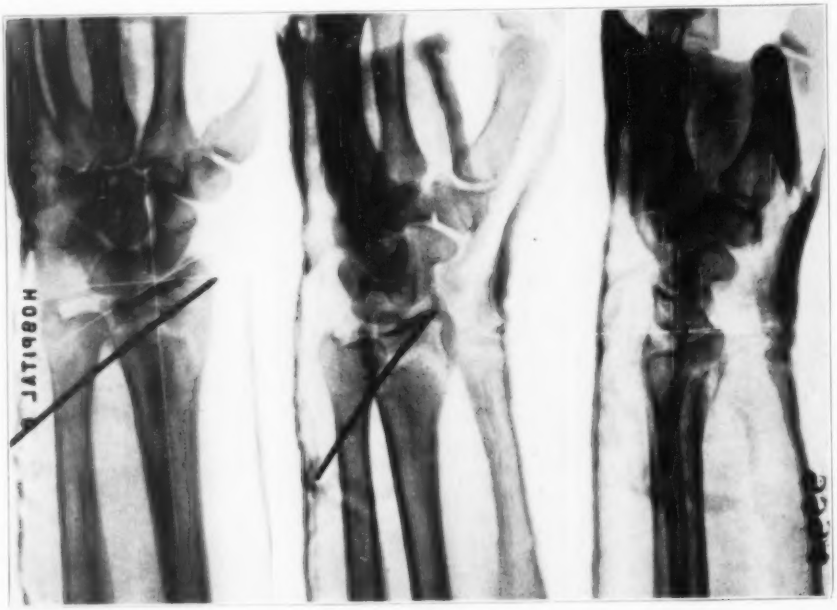

FIG. 6-B

Roentgenogram made immediately after reduction, showing restoration of anatomical alignment of all fragments.

styloid process of the radius. In two other cases so treated, low-grade infections developed around the site of the entrance of the wire. In some instances this method of reduction fails to restore completely the normal volar tilt of the radius; however, this did not preclude good function in those cases. Excessive traction may cause some distraction of the fragments. This, however, does not prevent good alignment of the articular surfaces; in no instance in the writer's series was union delayed. An eight-week period of internal fixation is mandatory; in several cases in which the wire was removed at the end of six weeks, shortening of the radius and malalignment of the fragments occurred.

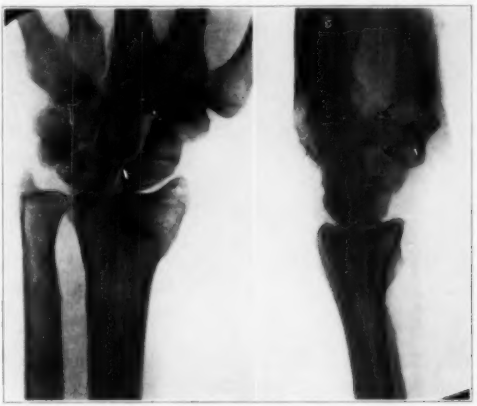

FIG. 6-C

End result twenty-three months later.

ANALYSIS OF TWENTY-EIGHT CASES

An effort was made to evaluate the cases in this series by the standards chosen by Gartland and Werley in order to compare the results obtained in the two series. The one difference between the two groups of cases was that all cases reported in this article were comminuted fractures of the articular surface of the radius.

In accordance with this plan, all cases studied were evaluated by the point system worked out by Gartland and Werley and the final end-result figures of both series were compared.

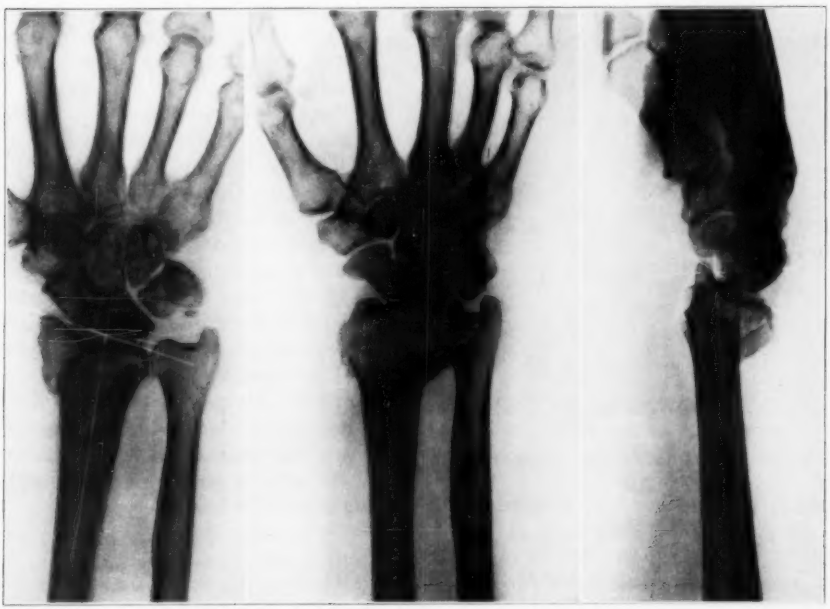

FIG. 7-A

Fig. 7-A: Case F. H. This patient had a comminuted fracture of the distal end of the radius with marked shortening.

For convenience the cases studied by these workers will be referred to as Group A and the cases in this series as Group B.

Tables I and II compare the functional results recorded in the two series of cases. A study of these tables reveals that the percentage of satisfactory results is considerably higher in the latter. This is significant in view of the fact that all the cases in Group B were classified as Groups II and III, whereas only fifty-three of the sixty cases in Group A fell into these categories.

FIG. 7-B

Fig. 7-B: Roentgenograms made immediately after reduction. In this instance some of the smaller fragments on the dorsum of the radius were not replaced in their anatomical position as depicted in the lateral view.

FIG. 7-C

End result thirteen months later.

Dorsal Tilt

Normally the articular surface of the radius is directed downward and forward; this volar tilt varies from 1 to 23 degrees, the average being 11 degrees (Fig. 3-C). It had been noted in Group A that failure to achieve complete anatomical restoration of the volar tilt of the articular surface does not preclude excellent function. A dorsal tilt of the articular surface of 5 degrees is compatible with normal function. (The volar displacement of the articular surface is measured in plus degrees and the dorsal displacement in minus degrees.) The relationship of the angle of the articular surface of the radius to the functional end results obtained in Group B is shown in Table III.

It becomes apparent that a residual dorsal tilt of the radius of −3.5 degrees is compatible with good function; this confirms the results obtained in Group A (Table IV).

Table III further demonstrates that although the tendency toward dorsal displacement of the distal radial fragments is largely minimized by the transfixion method, nevertheless, in some instances, particularly in severely comminuted fractures, displacement of a few degrees does occur. This may be the result of loss of bone substance at the fracture site and recession of the fragments during the process of healing. Fortunately, this malalignment has little deleterious effect on the over-all function of the wrist.

Radial Deviation

A characteristic anatomical feature of the normal radius is the articular surface which slopes from its styloid process proximally toward the ulna, forming an angle varying from 15 to 30 degrees (Fig. 3-A). In Group A the average on the normal side was recorded as 23 degrees. All the patients in Group B presented a decrease in this radial deviation in the

roentgenograms made before reduction. The relationship of the degree of radial deviation to function is shown in Table V.

When Table V is compared with Table VI, which is made up of the cases in Group A, it will be noted that the relationship of function to the degree of radial deviation in cases classified as excellent and good does not differ materially in the two groups. However, even those cases in Group B classified as fair reveal restoration and maintenance of the radial tilt. The decrease in function in these cases was not due to failure to achieve restoration of anatomical alignment but resulted from a certain amount of osteo-arthritis and some residual stiffness in the fingers.

It was interesting to note that most cases in Group B lost 1 to 3 degrees of the post-reduction correction of radial deviation during the period of immobilization or during the period between removal of the cast and the final follow-up examination. In those cases in which some loss of correction did occur, the amount was within the range compatible with good function. Moreover, a residual supination deformity was present in only one case in Group B, whereas in Group A, 52 per cent. of the patients presented this alteration. A residual supination twist increases dysfunction because it is always associated with marked diminution of the normal radial tilt. This was clearly demonstrated in Group A.

It became obvious that the method of treatment described obliterates the supination twist of the distal radial fragments, restores the normal radial deviation, and prevents excessive alterations in the angle of inclination of the radial articular surface during the healing period. All of these components of fractures in this region, if not corrected, result in pronounced dysfunction of the wrist.

Shortening

In Group A the average amount of residual loss of length of the radius recorded ranged from 1.7 millimeters in the patients with excellent results to 3.5 millimeters in those with poor results. It was noted in this series that shortening occurred in the interval between the reduction and the follow-up period; we were able to prove this because, in the majority of these cases, length had been restored at the time of reduction. In Group B no patient presented shortening of more than 2 millimeters in spite of the greater severity of these fractures as compared with those in Group A. Inasmuch as the supination deformity was corrected in all cases except one and inasmuch as the radial tilt was restored and maintained within normal limits in all instances, it is reasonable to assume that the few millimeters of residual shortening result from actual loss of bone substance at the time of the injury and recession of the fragments during the healing period. This amount of shortening does not impair function; however, shortening of more than four millimeters does preclude a satisfactory functional result.

Arthritis

Whenever the articular surface of a bone is severely comminuted, as in fractures of the distal end of the radius in Groups II and III, it is impossible to achieve anatomical restoration of all the fragments and some incongruity of the articulating surfaces must remain. Varying degrees of traumatic arthritis will result; if the normal mechanics of the joint has not been restored at the time of the reduction of the fracture, the severity of this lesion will be accentuated. In Group B arthritis as demonstrated by roentgenogram was the factor responsible for a functional classification of fair in five cases. In all these cases except one, the dorsal tilt, the supination twist, and decreased radial deviation had been restored to normal limits by the method described. A follow-up study at a later date may show that the number of cases in the less satisfactory classification is even higher.

In the majority of cases, moderate incongruity of the articular surfaces of non-weight-bearing joints as demonstrated by roentgenogram does not preclude good function. This observation has been confirmed clinically in both the scapulohumeral joint and the wrist

joint. In fact, severe alterations of the articular surfaces of the scapulohumeral joint are compatible with excellent function. It becomes obvious that the clinical rating of the functional capacity of a wrist joint is of greater significance than a rating based on roentgenographic study.

SUMMARY

A method of ulnar pinning after reduction by traction and manipulation in which all components of the fracture are corrected has yielded a satisfactory percentage of excellent and good results.

No infection occurred when a threaded wire was used and cut below the level of the skin. In two cases in which an unthreaded wire was used and the wire left protruding from the skin, a mild low-grade infection developed around the pin site which subsided readily upon removal of the pins.

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DISLOCATION OF THE TIBIOTALAR JOINT WITHOUT FRACTURE

AN UNUSUAL SKI INJURY *

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It would appear from the literature that a complete dislocation of the ankle joint without an associated fracture is a relatively uncommon injury. The only comprehensive report dealing with this type of injury is that of Wilson, Michele, and Jacobson who collected fourteen cases which had been reported since 1913 and to which they added two cases of their own. Eight of these dislocations were compound and eight were simple. In general, the mechanism of injury was a fall upon the foot, with the foot held in a position of equinus which forced the talus into a position posterior to the tibia. Reduction was comparatively simple in most of these cases. In the two presented by the authors cited, this was accomplished merely by traction after morphine sedation. It was apparent in the study that there had been extensive damage to the collateral ligaments in all instances, with partial or complete separation of the inferior tibiofibular joint in some. There have been three other reports on this condition,—one by Haines (a compound injury), another by Poinot and Doutre, and one by Woods. In the case reported by Woods, there was complete dislocation of the tibia and fibula posteriorly, without fracture. This could not be reduced under anaesthesia, for the tibia were locked behind the fibula. An open reduction with osteotomy of the fibula, two inches from its lower end, was necessary in order to obtain reduction.

In none of the cases cited above had the injury resulted during skiing. In this connection, it is significant that in the reports of Moritz and of Brothers, which deal specifically with skiing injuries of all kinds, there is no mention of any case comparable to the

* Reviewed by the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions of the author are the result of his own study and do not necessarily reflect the opinion or the policy of the Veterans Administration.

one herein presented. It seems worth noting in passing that, in the very large series of injuries sustained in parachute jumping which were reported by Ciecone and Richman, there is likewise no mention of any instance in which complete posterior dislocation of the tibiotalar joint without fracture occurred.

CASE REPORT

A college athletic instructor, twenty-six years old, was admitted to Wadsworth General Hospital, Veterans Administration, on December 29, 1950, with a history of injury to the left ankle ten hours previously while skiing. The patient stated that in attempting a turn he fell, locking the left ski over the back of the right one. In this position his foot was in marked plantar flexion and the left knee was partially flexed. A light splint had been applied and he had been brought to the Hospital, an eight-hour trip from the scene of the injury.

On admission, examination of the left lower extremity revealed an obvious severe posterior dislocation of the ankle. The foot was in marked plantar flexion and its long axis was almost parallel to that of the tibia. The skin and the soft tissues over the anterior surface of the ankle joint were taut and revealed the outline of the anterior surface of the tibia and fibula. The tendo achillis was plainly outlined posteriorly; it was so taut that depressions along either side of the tendon in the skin and soft tissues were visible. There was minimal swelling of the ankle region and no discoloration. The posterior tibial pulsation was present, while the anterior tibial pulsation was absent. The patient complained of only moderate discomfort. Sensation was intact. Roentgenograms showed a complete posterior dislocation of the tibiotalar joint with the talus lying slightly lateral and completely posterior to the tibia and fibula. No fracture was noted (Fig. 1).

FIG. 1

Before reduction of the dislocation.

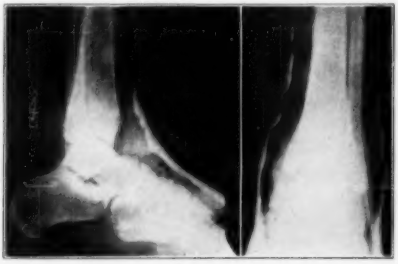

FIG. 2

After reduction.

FIG. 3

FIG. 4

Four months after the injury.

The patient was taken to surgery immediately after admission, and, under spinal anaesthesia, reduction was done. Gentle traction, with the knee bent at 45 degrees, was sufficient to obtain reduction. Roentgenograms made promptly after the reduction showed complete restoration of the normal alignment of the ankle in both views. Although there was little evidence of swelling about the ankle prior to reduction, rapid swelling, particularly of each side, occurred afterward. The intense stretching of all the soft parts over the joint apparently acted as a tamponade which prevented hemorrhage into the area. A long cast was applied to the limb with the knee in 20 degrees of flexion. Check x-rays, through plaster, showed the reduction to be maintained (Fig. 2). There was no pain or swelling following immobilization.

FIG. 5

Left ankle four months after reduction.

At the end of seven weeks, a short cast was applied to the leg. Weight-bearing was permitted two weeks later. Immobilization, however, was maintained for twelve weeks. Four months from the time of the initial injury, the patient was walking without assistance, and he had no complaint of pain or swelling. Examination of the ankle at that time revealed a full range of motion without any swelling or local tenderness (Figs. 3 and 4). X-rays showed a normal appearing ankle joint without any suggestion of previous trauma or of post-traumatic rarefaction (Fig. 5).

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FAILURE OF CORTISONE TO DELAY OR TO PREVENT THE HEALING OF FRACTURES IN RATS*

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In clinical observations on patients who were being treated with ACTH for rheumatoid arthritis or erythema multiforme, Ragan and his associates [5] noted that operative wounds and decubitus ulcers healed less rapidly in three patients who were being treated with ACTH than in patients who were not receiving ACTH. Ragan and his associates [4,6,7] also demonstrated that cortisone inhibited the growth of granulation tissue and retarded connective-tissue formation in open wounds of the ears of rabbits and that the activity of the fibroblasts and the formation of new blood vessels were markedly depressed. It was suggested that the inhibition of the re-activity of the connective tissues may explain the effect of cortisone on the diseases involving mesenchymal tissue,—the mechanism being one in which the induced hyperadrenalism interferes with the response of the mesenchymal tissues to trauma and causes a remission of the symptoms resulting from such response. It was further noted by Blunt and his associates [1] that, in experimental fractures in eight rabbits which were being given twenty-five milligrams of cortisone daily, the growth of new blood vessels and the reconstruction and differentiation of connective tissue were retarded, as compared with the changes which occurred in the control group of eight rabbits which were not given cortisone. During the first four days after the fracture, the changes in the two groups were the same, but it was noted that, after this time, tissue healing in the cortisone-treated animals was retarded. This was evidenced by the presence of new-bone trabeculae by the eighth day in the control rabbits, whereas no such trabeculae were seen in the cortisone-treated rabbits. Their experiments were not continued longer than eight days. Stinchfield used cortisone locally and systemically (ten milligrams per kilogram) for three weeks after experimental arthroplasty of the hip in a series of dogs and in patients. In conjunction with the cortisone, oxidized cellulose was used to limit new-bone formation. Twelve such experiments on dogs were performed; and it is concluded that, in the cortisone-treated animals, there was less thickening of the capsule, more free motion, less crepitation, and no inflammatory reaction.

We were rather surprised at the above reports because we had operated upon a few patients who were under active treatment with cortisone, and not only had we not noted anything wrong with the manner in which the wounds healed, but we had been impressed with the relatively painless and smooth postoperative course of these patients. This was especially true of three arthritic patients who had been subjected to reconstruction operations on the feet and in whom the postoperative swelling and pain seemed to be much less than usual.[3]

Consequently, it seemed to us that the effect of cortisone on the healing of bones and of other tissues warranted further study. In this paper we shall report observations on the healing of experimental fractures of the humerus in a series of 122 white rats, seventy-three of which were treated with cortisone†. The animals were sacrificed at intervals of from two to thirty-five days.

*Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 21, 1951.

† The cortisone acetate used in these experiments was generously furnished by Merck & Co., Inc., Rahway, New Jersey, through the cooperation of the United States Army.

MATERIAL AND METHODS

In a series of 122 normal, young adult, albino rats, weighing from 180 to 220 grams each, the right humerus was fractured manually by bending it over the sharp edge of a container after the animal had been anaesthetized with ether.

The animals were divided into three groups:

Group I consisted of thirty rats, fifteen of which were each given four milligrams of cortisone acetate intramuscularly on the day of the fracture and daily thereafter until they were sacrificed. The other fifteen served as controls. Five of each group were sacrificed with an overdose of ether on the seventh, the fourteenth, and the twenty-first day after the fracture. The fractured extremity was then dissected down to the bone, care being taken to disturb the site of the fracture as little as possible, and the specimen was fixed in a 10 per cent. solution of formalin. The specimens were then x-rayed and later decalcified and embedded in paraffin; microscopic sections were made which were stained with hematoxylin and eosin.

Group II consisted of forty rats. In these a stainless-steel pin or needle was inserted into the medullary canal of the humerus before it was broken. Under ether anaesthesia and with aseptic technique, a small incision was made through the shaved and prepared skin over the acromion. This was elevated to expose the proximal end of the humerus; and, with a stab-blade knife, a small hole was drilled through the cortex of the head of the bone. Then the needle or pin was thrust down into the medullary canal and the incision in the skin was sutured. The humerus was then fractured over the edge of the container; if necessary, it was straightened after the fracture. The purpose of the medullary pin was to prevent gross displacement of the fragments.

In twenty of these animals, two milligrams of cortisone was injected into the fracture site on the day of the fracture and each day thereafter for five days, after which two milligrams was injected intramuscularly each day until the animals were sacrificed. The other twenty animals served as controls and were treated in the same manner, except that they did not receive cortisone. The animals were sacrificed in groups of five on the seventh, the fourteenth, the twenty-first, and the twenty-eighth day after the fracture, and the extremities were studied as were those of the first group, the pins being removed before the specimens were placed in paraffin.

Group III consisted of fifty-two animals in which the humeri were fractured after medullary pins had been inserted. Thirty-eight of these animals were each given three milligrams of cortisone intramuscularly at the time of the fracture and each day thereafter until they were sacrificed. They were sacrificed at twenty-four, forty-eight, sixty, and seventy-two hours after the fracture and on the fifth, the seventh, the tenth, the fourteenth, the twenty-first, the twenty-eighth, and the thirty-fifth day after the fracture. The other fourteen animals served as controls, supplementing those in Group II. The extremities were then studied in the same manner as were those in the two preceding groups.

OBSERVATIONS

Gross Examination

In examining the gross specimens immediately after autopsy, the points which were particularly studied were: the amount of hemorrhage present, the presence and size of the interfragmentary clot, the firmness of the callus on palpation, the size of the callus, and the stability of the fracture site. In the specimens which were examined twenty-four, forty-eight, and sixty hours after the fracture, there was no perceptible difference between the controls and the animals which had been treated with cortisone. At seventy-two hours in the control group, hemorrhage had disappeared both from the region of the fracture and from the operative wound where the pin had been inserted, whereas some hemorrhage was still present at both sites in the animals which had been treated with cortisone. In each

group, there was a small, grayish-white, spindle-like swelling around the fracture site. In the cortisone-treated animals, this swelling was about one and one-half as large as was the one in the control group, and it was more pink in color than was that in the controls. The ends of the bones were freely movable in each group.

In the five-day animals, the fusiform swelling around the fracture was still quite soft on palpation and again was larger in the cortisone-treated group. It is to be noted that by the fifth day all of the animals in which a medullary pin had been inserted into the humerus were bearing weight upon the fractured extremity and were using it quite freely. In the seven-day group, the fracture was surrounded by large, yellowish-white callus which was soft on palpation; there was very little movement of the ends of the bones in either group. In the cortisone-treated group, the callus was consistently larger. At fourteen days, there was still some residual intramuscular hemorrhage in a few of the animals which had received cortisone, while there was none in the control animals. The callus was somewhat smaller in size than in the ten-day animals and the bone ends appeared to be quite solidly fixed together. The callus had changed color and was now grayish white instead of yellowish white. In the twenty-one-day specimens, the callus was considerably reduced in size and was firm in consistency, grayish white in color, and the bone ends appeared to be firmly united. This reduction in the callus and further hardening was again evident in the twenty-eight-day specimens; the bones appeared to be even more firmly united, and, in the animals of these two latter groups, there was less difference in the size of the callus than in the early groups. In other words, the callus in the cortisone-treated animals was scarcely greater than in the controls, if at all.

In the group in which the humeri were simply broken and in which no internal fixation was used, gross deformities of the leg were present in most instances and the bone ends tended to over-ride one another. In the majority of the specimens there was little or no tendency to union of the two fragments. This was true both of the cortisone-treated animals and of the controls. In some cases the bone ends were surrounded by and sealed with relatively large bulbous masses of callus. In others the bone ends lay free in a blood clot; and, in the later specimens, they were surrounded by a cystlike cavity, thus indicating that a definite non-union was to be expected. In some animals, the masses of callus around each bone so fused that lateral union occurred with shortening and usually with a considerable degree of angulation. In these specimens, there was a definite tendency on the part of the animals which were treated with cortisone for more hemorrhage to be present and for the extravasated blood to persist longer around the fracture site than in control animals. Also, it was our impression that, in the cortisone-treated animals, the mass of callus was larger than that in the controls. In so far as union or non-union occurred, we noted no difference between the cortisone-treated animals and the controls.

X-ray Appearance

Roentgenograms were made of all specimens after they had been fixed in formalin. They showed the positions of the bones; in the later specimens at twenty-one, twenty-eight, and thirty-five days there was questionable union in some of the specimens, and the callus was visible. While there were minor individual differences in the amount of callus and in the degree of union, no consistent difference could be detected in the roentgenograms of the two groups (Figs. 1-A and 1-B).

Microscopic Examination

In the forty-eight-hour specimens (Figs. 2-A, 2-B, and 2-C), the ends of the fragments of the bone in the zone of the fracture were surrounded by a blood clot which contained large numbers of red cells. At a variable distance from the center of this clot the cells stained less deeply and the mass was composed of fibrin which contained some red cells but which also contained an unusually large number of round cells and leukocytes (Fig. 2-A). The round cells appeared to be mononuclear phagocytes. The fibrin contained numerous vacuole-like cavities surrounded by a delicate pink-staining network. Very few fibroblasts and no blood

FIG. 1-A

X-rays of humeri of rats.

Top row: Five control humeri three weeks after fracture.
Bottom row: Five cortisone-treated humeri (2 milligrams daily), three weeks after fracture.

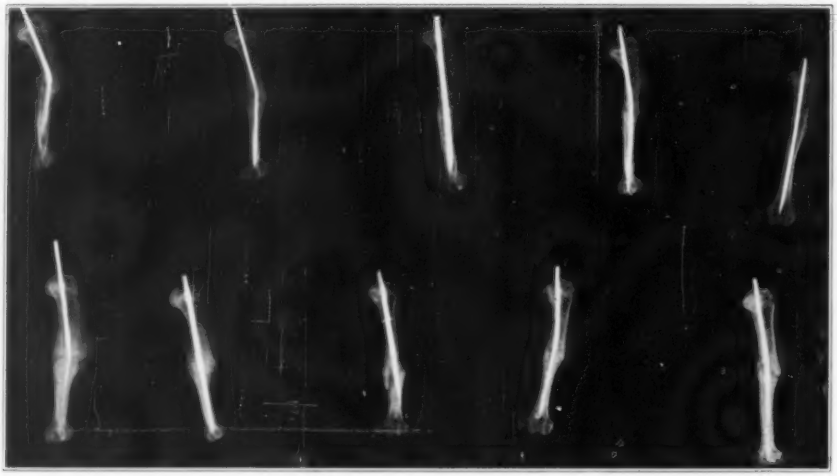

FIG. 1-B

X-rays of humeri of rats.

Top row: Five control humeri with medullary-pin fixation, three weeks after fracture.
Bottom row: Five cortisone-treated humeri with medullary-pin fixation, three weeks after fracture.
Note that the degree of union is practically the same in the control humeri as in the humeri of animals treated with cortisone and that medullary fixation had a beneficial effect on fracture healing.

vessels were seen in this area. Where the fracture was surrounded by muscle tissue, the fibrin clot and cells involved the adjacent muscle. A short distance up the shaft of the bone there was evidence of increased activity in the cellular layer of periosteum. The fibrous layer of the periosteum in places appeared to be lifted up from the bone, and the intervening area was occupied by three or four layers of cells (Fig. 2-C). In most instances these were rather loosely arranged and resembled osteoblasts. In some instances, however, they were quite compactly arranged and consisted of a layer four or five cells thick which were enclosed in a homogenous network and which seemed to be forming a layer of young connective tissue. In other sections these cells resembled bone cells, were more rounded in appearance, and were embedded in a homogenous matrix which stained a light pink; these appeared to be an example of very early bone formation in membrane.

Fig. 2-A: A 32-millimeter section of the humerus of a forty-eight hour control rat. Cortex of the end of fragment showing hematoma. The beginning organization of clot is visible in the upper right section.

Fig. 2-B: A 32-millimeter section of the humerus of a forty-eight hour cortisone-treated rat. Hematoma is visible around the end of the fragment and in the marrow canal. Reaction beneath the periosteum is visible in the upper right section.

Fig. 2-C: An 8-millimeter section of the humerus of a forty-eight hour control rat. Proliferation of cells (osteoblasts?) is visible beneath the fibrous layer of periosteum as in Fig. 2-B.

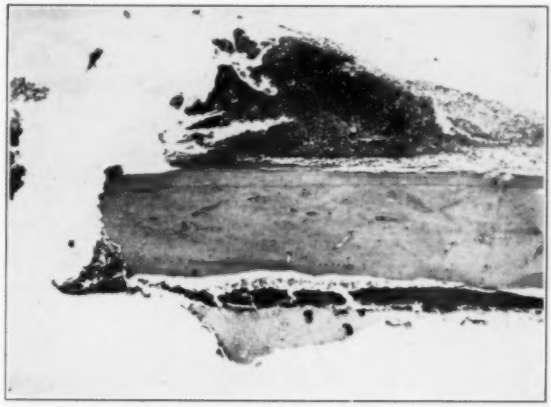

FIG. 2-A

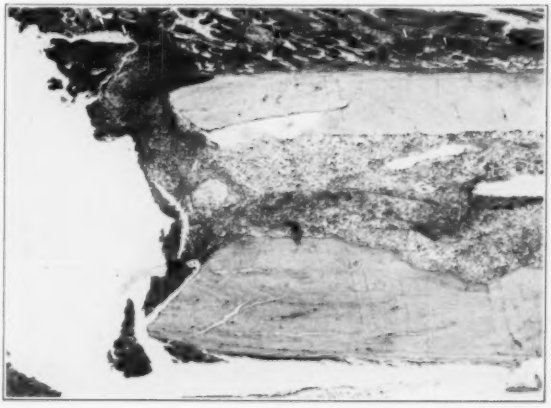

FIG. 2-B

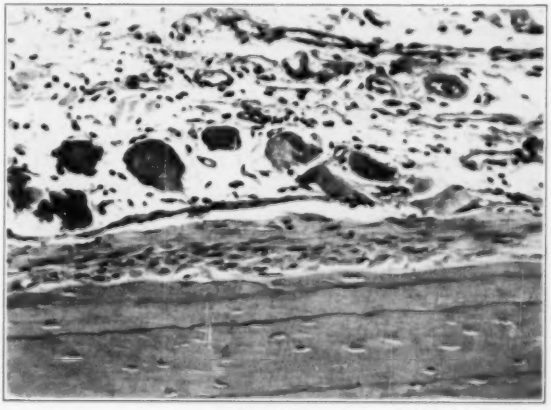

FIG. 2-C

The process was too early for the formation of trabeculae. In some areas adjacent to the fracture, the cells were round and lay in small vacuoles; these appeared to be a very early formation of cartilage. The condition existed in both the control animals and in those which were given cortisone. The subperiosteal proliferation and the beginning differentiation of these cells into bone and cartilage were present in each and extended for about the same distance up the shaft of the bone away from the fracture. Other than the fibrin and blood clot, no definite change was seen in the medullary canal.

In the sections of humeri removed sixty hours (two and one-half days) after the fracture, the layer of proliferating cells beneath the fibrous layer of the periosteum was a good deal thicker than that in the forty-eight-hour specimens; and, in some sections, it was about one-third the thickness of the cortex and extended up the shaft from the fracture for a distance of about three times the diameter of the shaft of the bone. The deeper layers of these proliferating cells contained a thin sheet of newly formed, pale appositional bone which was applied to the cortex of the humerus. Numerous short, thick trabeculae of bone projected from this appositional layer and extended out into the mass of proliferating cells (osteoblasts). Some of these trabeculae branched and were continuous with similar trabeculae which lay parallel with the surface of the bone. A moderate number of capillaries were present in this tissue. The cartilaginous callus had not yet appeared; but, in a few sections, a few cells, which we believe were cartilage cells in a hyaline matrix, were seen in the margins of the

FIG. 3-A

Fig. 3-A: A 32-millimeter section of humerus from a three-day control rat. Clot is visible between fragments and cartilage opposite the fracture site with subperiosteal new-bone formation on either side.

Fig. 3-B: A 16-millimeter section of humerus of a three-day cortisone-treated rat. Clot between fragments and cartilage opposite the fracture site is much the same as that shown in Fig. 3-A, but new-bone formation and cartilage are more abundant.

Fig. 3-C: A 16-millimeter section of humerus of a three-day cortisone-treated rat (as in Figs. 3-A and 3-B). Section shows new-bone trabeculae in the medullary canal as well as around the fracture and beneath the periosteum.

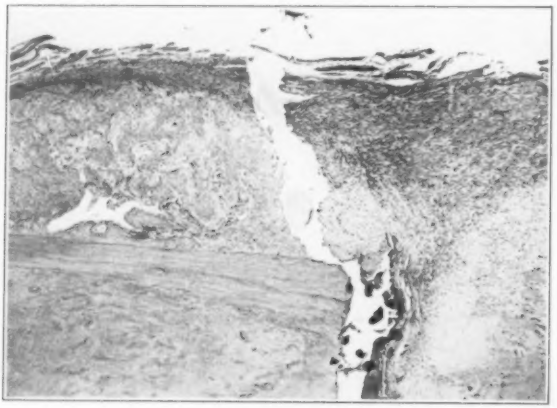

FIG. 3-B

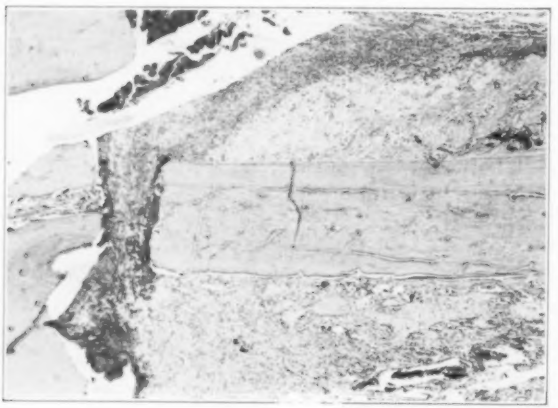

FIG. 3-C

blood clot around the ends of the fragments.

At the end of three days (Figs. 3-A, 3-B, and 3-C), there was further disappearance of red cells from the clot around and between the ends of the fragments. There was very marked cellular proliferation with the formation of new bone beneath the periosteum; this extended up the shaft for about three times the diameter of the shaft of the bone, and the thickness of the layer of new bone in some instances was approximately that of the cortex of the bone. This new bone was being formed in membrane and lay between the fibrous periosteum and the cortex. Some blood vessels had grown into the area, and in some places there were a large number of fibroblasts or osteoblasts, forming a rather thick subperiosteal layer which was traversed by a relatively small number of trabeculae of bone. This bone stained a light pink, its cells were for the most part quiescent osteocytes, and its surface was covered with a layer of deeply staining osteoblasts. The interstices were filled with lightly staining cells which resembled fibroblasts; a few capillaries were seen. Near the ends of the fragments, the trabeculae of bone were no longer formed and the two fragments were bound together by a mass of fibroblasts which in some areas passed over into hyaline cartilage (Fig. 3-B), and this in turn merged into the lightly staining coarse bone trabeculae which had formed beneath the periosteum a short distance proximal and distal to the fracture. In some specimens, this mass of cartilage was quite large and had almost completely replaced the blood clot which surrounded the fracture site; the cartilage

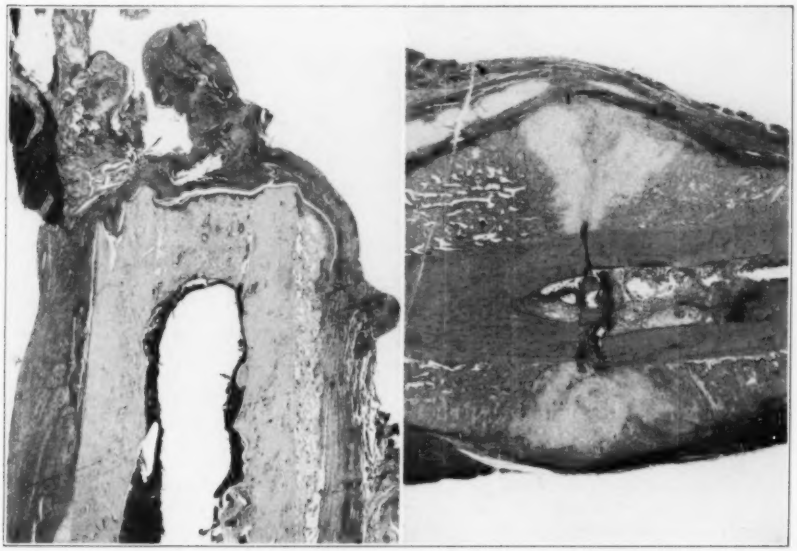

FIG. 4-A FIG. 4-B

Fig. 4-A: A 32-millimeter section of the humerus of a seven-day cortisone-treated rat in which no fixation of the fragments had been used. Section shows the end of the fragment with the medullary canal blocked by a plug of cancellous bone. Subperiosteal new-bone formation and cartilage are seen around the end of the fragment.

Fig. 4-B: A 32-millimeter section of the humerus of a seven-day cortisone-treated rat. Thick cartilaginous callus and cuffs of subperiosteal bone are to be seen around the fracture.

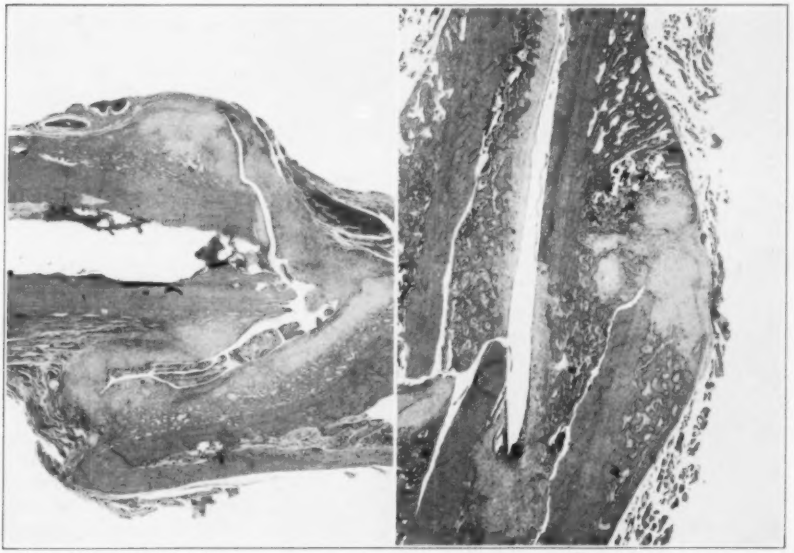

FIG. 4-C FIG. 4-D

Fig. 4-C: A 32-millimeter section of the humerus of a fourteen-day cortisone-treated rat in which medullary fixation had not been used. Cavity between the fragments with cartilaginous callus and subperiosteal new-bone formation around the ends of the fragments is shown.

Fig. 4-D: A 32-millimeter section of the humerus of a twenty-one-day cortisone-treated rat. Cartilaginous callus is less in amount and is being replaced by cancellous bone.

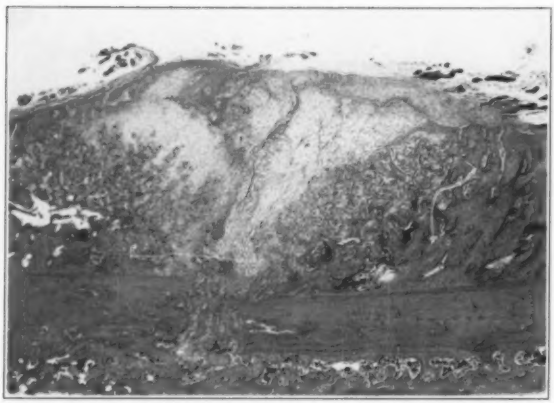

FIG. 5-A

FIG. 5-B

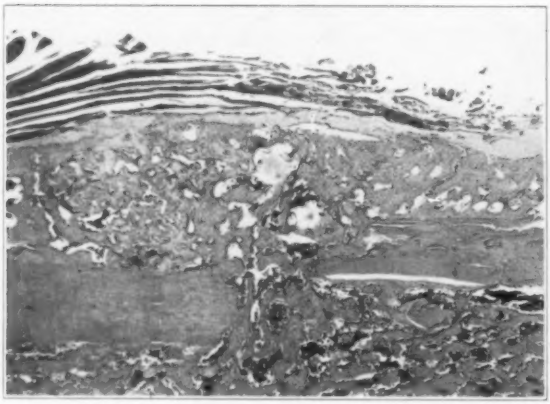

FIG. 5-C

Fig. 5-A: A 16-millimeter section of the humerus of a twenty-one-day cortisone-treated rat. Cancellous bone is filling marrow canal and is bridging the space between fragments; it is invading cartilaginous callus around the fracture.

Fig. 5-B: A 32-millimeter section of the humerus of a twenty-one-day cortisone-treated rat. The cartilaginous callus is being replaced by cancellous bone.

Fig. 5-C: A 16-millimeter section of the humerus of a twenty-eight-day cortisone-treated rat. Cancellous bone has filled the medullary canal, has united the ends of the fragments, and has almost completely replaced the cartilaginous callus.

cells appeared to have been formed by direct transformation of the fibroblasts. At this time, there were still some disintegrating blood cells in the clot around the ends of the fragments, which was being invaded by the fibroblasts and newly formed cartilage.

In the marrow canal of the specimens of humeri removed three days after fracture, there was considerable proliferation of the fibroblasts and some new-bone formation (Fig. 3-C). Here too the trabeculae were rather coarse; they stained lightly and merged into masses of fibroblast-like cells in a homogenous pink groundwork. This appeared to be the result of invasion by connective-tissue cells and the transformation of the fibrin clot which was present in the sections of the forty-eight-hour specimens, but in which no new-bone formation could be detected. As one approached the site of the fracture, the fibroblasts gave place to bone trabeculae which tended to occlude the marrow canal, except for the space occupied by the medullary pin. In some sections, minute fragments of adult bone were seen to be caught in this mass of newly formed bone in which they appeared to be living. In some instances small cavities were present in the blood clot which surrounded the ends of the fragments; these cavities might lie between the ends of the fragments and extend out into the blood clot. Some of them contained coagulated blood with masses of disintegrating red cells, small masses of fibrin, and small bone fragments. They were lined by fibrin.

At five and seven days (Fig. 4-A), there was a tendency to hardening and condensation of the trabeculae

of cancellous bone beneath the periosteum near the ends of each fragment; and, at that time, the fibroblast in the interstices had formed a more definite connective-tissue weld which contained more blood vessels and some fat cells. There was also increased thickness of this cuff of cancellous bone, as well as of the cartilage mass which surrounded the fracture and which was very close to and between the ends of the fragments (Fig. 4-B). There was also considerable osteoclastic activity in some sections with the production of lacunae in the margins of the fragments. In others no such changes were seen. The ends of the fragments were beginning to show empty lacunae; these were quite well marked in the seven-day specimens. In most specimens there was still some of the blood clot around the ends of the bone. In some of the specimens which did not contain a wire and in which the bone ends were not in contact, a plug of cancellous bone extended entirely across the medullary canal (Fig. 4-A).

In some of the seven-day and fourteen-day specimens, new trabeculae could be seen to extend from the medullary canal (the endosteum). These were applied as appositional bone to the ends of the fragments; and, in the fourteen-day specimens, the trabeculae formed a delicate cancellous bridge which united the proximal and the distal fragments. The mass of cartilaginous callus between and opposite the two bone ends had reached its maximum size at about two weeks. The trabeculae in the cancellous bone were quite robust and were beginning to invade the cartilaginous callus. In some of these sections, however, there was still a small cavity and some blood clot between the ends of the fragments.

At three weeks (Figs. 5-A and 5-B), the cartilage had in many instances almost entirely disappeared and had been replaced by cancellous bone, although there were still small areas of hyaline cartilage in the vicinity of the fracture line. The cancellous bone had in places been absorbed to a point where there was a rather thick cortex of new bone parallel with the shaft, and the intervening space was occupied by bone marrow and contained only a few trabeculae. In some other specimens the mass of hyaline cartilage was still large and there was still a small cavity between the ends of the fragments. Likewise in these specimens the absorption of the cancellous bone had not progressed to the degree mentioned above, and the trabeculae of cancellous bone surrounding the shaft near the ends of the fragments were quite heavy and the marrow spaces were still quite small, although some of them contained what appeared to be normal red bone marrow and were well supplied with blood vessels.

At four weeks (Fig. 4-C), the union between the fragments was in most instances more firm. There was further replacement of the cartilaginous callus by the cancellous bone and there was further condensation, even though at this stage some of the specimens showed cartilage not yet replaced by bone. The same was true of the specimens removed at five weeks after the fracture; here the changes toward union by bone showed further progress.

The above microscopic observations were made on the specimens in which the position of the fragments had been satisfactorily controlled by a medullary wire. In specimens in which the wires were not inserted, there were the same type of changes except that not infrequently a large cavity was found between the ends of the fragments and the hematoma was larger.

In all three groups of animals, it was not possible from the microscopic examination of the fracture site and study of the callus to determine whether or not the rat had been treated with cortisone, for the progress of union was practically identical in the treated animals and in the control animals. In the experiments which had been continued over a period of three or more weeks, there was a definite difference in the width of the epiphyseal line in the treated specimens and in the controls — the epiphyseal lines in the cortisone-treated animals were considerably narrower than were those of the controls.

DISCUSSION

In the experiments in which the position of the fragments was controlled by the medullary pins, the union between the two fragments seemed to proceed in an orderly manner and the pins apparently did not interfere with union. A mass of hyaline cartilage was formed around the site of the fracture and above and below this were cuffs of cancellous bone. These were present within sixty hours and were well marked three days after the fracture. The callus and cuff of bone continued to increase in size for a period of about two weeks. After that time they decreased in size; the cartilage was invaded by blood vessels and was transformed into or was replaced by trabeculae of new bone which were continuous with the subperiosteal bone around the shafts and also by new bone which was continuous with the cancellous bone that grew out from the endosteum and invaded the cartilage from within.

The first union by bone was by appositional bone trabeculae which were continuous with the endosteal new bone. The union was quite firm in four weeks, but there was still some cartilage callus left at four and even at five weeks. It is probable that several months would elapse before complete transformation of the shaft occurred.

The fractures in which no internal fixation was used varied greatly in rate and character of union and we were not able to draw any conclusions from the study of the specimens except that non-union was quite frequent and there seemed to be no difference between the cortisone-treated animals and the controls. Microscopically it was not possible for us to detect any difference in the rate or manner of healing of the experimental fractures between the cortisone-treated animals and the controls.

It is difficult for us to explain our negative results, for other authors have found that new-bone formation was suppressed by cortisone. However, the experiments of Blunt and others were done on rabbits. In the early paper by Ragan [6] and his associates, it was stated that the rat is very resistant to cortisone. It is quite possible that with a larger dose of cortisone we might have been able to produce definite differences in the rate of healing in the fractures in our animals. However, three of our five rats, which were receiving four milligrams of cortisone daily and which were to have been sacrificed three weeks after the fracture, died before this time had elapsed; we attributed the deaths to the toxic effects of the large doses of cortisone. Winter and others administered daily doses of three milligrams of cortisone to adult male rats and found that the animals ceased to grow and to gain weight—this occurred in spite of the fact that the cortisone-treated animals consumed 47 per cent. more food that did the control animals—and that their hair did not regrow on the areas from which it had been plucked. On autopsy they found that the thymus and the adrenals were reduced in size and that the epiphyses of the long bones were narrowed.

As evidence that the rats were affected by the doses of the cortisone which we used, it may be stated that, in all of our animals in which the cortisone was continued for two weeks or more, there was a decrease in the rate of growth, loss of the normal sheen of the hair, and no regrowth of hair on the skin of the shoulders from which it had been shaved preparatory to the insertion of pins, as there was in the controls. Also these animals at autopsy showed a decrease in the size of the adrenals as compared with those in the controls. In examining the epiphyses of the long bones in our animals which had received cortisone for three weeks or longer the epiphyseal cartilages seemed to be considerably narrower than were those of the controls. However, as the sex and age of our animals were not controlled, we are not in a position to make any definite statements on the width of the epiphyses. The same is true of the changes in the metaphysis as noted by Follis.

Further evidence that young adult rats may be affected by a daily dose of two milligrams of cortisone was obtained in a series of fifty animals, in which we injected a suspension of 0.5 gram of talc powder into the peritoneal cavity in order to study the effect of cortisone on the formation of peritoneal adhesions. In the control animals, the talc was largely surrounded by granulomatous masses and the intestines were matted together by adhesions, while in the animals which had received two milligrams of cortisone daily the talc was widely dispersed and very few adhesions were present. The only difference in the healing of the fractures which we were able to notice was that in the cortisone-treated animals the masses of callus were usually larger and the evidence of hemorrhage in the traumatized areas persisted over a longer time. Microscopically the specimens from the two series of animals were practically identical.

CONCLUSION

The administration of from two to four milligrams of cortisone daily to young adult white rats did not perceptibly delay the healing or alter the microscopic appearance of the process of repair of experimental fractures in these animals.

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DISCUSSION

Dr. Keene O. Haldeman, San Francisco, California: Following the clinical demonstration that cortisone and ACTH possess the remarkable power of causing a prompt remission in patients with acute rheumatic fever, rheumatoid arthritis, and the other so-called collagen diseases, it has been assumed that these substances act by depressing the formation of connective tissue. We know that newly formed connective tissue provides the framework upon which the pre-osseous substance is laid. The important question to be answered is whether or not the depressing effect of cortisone on connective-tissue activity retards or prevents the normal healing of fractures. Whether or not cortisone inhibits that process will be decided not on theoretical grounds, but on the basis of animal experimentation and clinical experience. The paper just read presents a well conceived and executed investigation. It establishes conclusively that cortisone does not influence unfavorably the healing of fractures in the rat. As the formation of fracture callus in rodents is notoriously rapid, it is desirable that clinical evidence in the human be presented. In this connection, I wish to offer one case from my experience.

Recently a woman, seventy-seven years old, suffering from a severe and generalized rheumatoid arthritis of ten years' duration, intending to pass through San Francisco on her way to an arthritis clinic, was dropped as she was being carried down the gangplank in her wheel chair. She sustained fractures of the tibia and fibula of both legs. These fractures were at once manipulated and the limbs were immobilized in long casts. Beginning two days after her accident, she was given cortisone intramuscularly in 100-milligram daily doses. This was continued for eighteen days, after which the cortisone was stopped for fear that the healing of the fractures might be retarded. The drug after ten days produced a striking improvement in her arthritis, although her symptoms recurred ten days after it was discontinued. Roentgenograms made seven weeks after the injury showed strong evidence of healing of all fractures. At the end of nine weeks, no abnormal mobility of the fractures could be demonstrated and it seemed safe to remove the casts. Although it may be said that the administration of cortisone for eighteen days was for too brief a period to be conclusive, that period covered the time during which the procallus is normally formed. It is to be hoped that additional clinical evidence will be forthcoming.

Dr. Philip D. Wilson, New York, N. Y.: I want to add some experimental evidence of our own which is not yet complete but which is now being studied.

We have done a series of experiments on dogs with transplantation of a portion of the ulna from paw to paw, using this fresh homogenous graft immediately on one side and a frozen transplant on the other. One series of these animals was given cortisone and one was not. We gave cortisone in a dosage which was based entirely on the weight of the animal and which was comparable with the dosage used in human beings. Since we are just now going over the evidence of this study, it is perhaps too early to speak; but I can confirm what Dr. Key and his associates have said that healing in cortisone-treated animals is the same as in those which were untreated. I think one of the reasons the early evidence led to different conclusions is that the dosage in some of the cases was much too large. It was very difficult at that time to know what the dosage should be, and overdosage was often employed. Certainly that is not the situation with which we deal now when we have human patients.

(*Continued on page 677*)

CONGENITAL ABSENCE OF THE ODONTOID PROCESS

A Case Report

BY GEORGE MIYAKAWA, M.D., CHARLESTON, WEST VIRGINIA

Complete absence of the odontoid process is an uncommon congenital anomaly. Of the cases previously reported by Roberts, Weiler, Scannell, and Ivie, all came to light following relatively trivial neck injuries. In the absence of the odontoid process, it would appear that the atlanto-axial joint is unstable. The possibility of early childhood fracture with atrophy may be considered.

FIG. 1

FIG. 2

A white man, twenty-nine years old, gave a history of injury to the neck at the age of sixteen as a result of wrestling. The injury was sustained by a sudden twisting motion. There was temporary paralysis of both arms and hyperaesthesia and paraesthesia along the posterior portion of the neck, extending up into the occipital region of the scalp. Tingling was felt down both arms as far as the finger tips. Hyperaesthesia persisted for approximately ten days; the paralysis of the arms was noted only for a matter of a few minutes. No medical attention was sought and no x-rays were made.

The patient was asymptomatic for a period of three years, at which time, while tumbling, he again sustained a sudden jarring injury to the base of the spine. This resulted in a recurrence of the tingling along both arms and hyperaesthesia along the posterior portion of the neck and the occiput. These symptoms lasted only a few days. Again, no medical attention was sought.

In March 1951, the patient, striking his head on a large wooden beam, produced temporary paralysis of both arms together with uncontrolled, uncoordinated movement of both arms. He also had a recurrence of the tingling, hyperaesthesia, and paraesthesia as previously described. At this time the symptoms persisted for about three weeks, although the paralysis was present for only a few minutes. X-rays were made following this injury (Figs. 1 and 2).

On November 8, 1951, the patient had no symptoms and no limitation of motion at the neck. General physical examination and neurological tests were negative.

COMMENT

This patient, who is a physician, is leading a normal life. There is, however, always the danger of a recurrence, with possible permanent damage. It is felt that surgical fixation after the practice of Weiler is desirable.

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DISCUSSION

Failure of Cortisone to Delay the Healing of Fractures

(*Continued from page 675*)

Dr. Edgar M. Bick, New York, N. Y.: I would like to take a moment to exhibit some of the healthy skepticism which Dr. Key has shown. I will be very brief. There are two things here which I have missed completely. In the first place, we do know that the use of cortisone does suppress fibrosis; and in the second place Dr. Odell has repeatedly said that in the cortisone-treated animals there was a longer period of retention of hemorrhage and a greater amount of callus. Obviously there was a difference between the two series of rats and it was a definite histological difference. Other facts too must not be allowed to eliminate that. The fact that the fractures eventually healed is excellent. No one has ever said that they would not heal. Secondly, the healing of fractures in these laboratory animals is known to be much more rapid than it is in human beings. Third, although much more study of the specimens would be needed on my part to confirm it, it seemed from the roentgenograms of the two groups that the amount of callus in the controls was either more dense or larger than that in the cortisone-treated animals.

In regard to Dr. Wilson's statement that the earlier evidence was due to an overdose of cortisone, if one does not give too much cortisone, we may not interfere with healing. If the statement is true that an overdose of cortisone does interfere with the healing of fractures, then I do not believe we have the right to say that in general the use of cortisone does not interfere with the healing of fractures.

Dr. Key (closing): We did some of our clinical work on cortisone before we did our experimental work. We had about twenty-two cases which Dr. Ford and I reported at the St. Louis Rheumatism Society on March 5, 1951.[a]

There was a slight difference between the cortisone-treated rats and the control rats, because the hemorrhage persisted longer in those which were given cortisone; but the difference was so slight that I could not detect it in the microscopic sections. At forty-eight hours there was a definite reaction beneath the periosteum with proliferation of cells in addition to the hemorrhage and reaction in the surrounding tissues. This subperiosteal proliferation was not present around the ends of the fragments, but began about the width of the bone up from the fracture and extended up about three times the width of the bone. At sixty hours this subperiosteal mass of proliferating cells had bone trabeculae in it and at seventy-two hours there was a layer of bone trabeculae beneath the periosteum which was as thick as the cortex of bone.

At forty-eight hours one could see in some areas a little condensation around these connective-tissue cells, so that it looked as though they were in a matrix which was beginning to gel. At sixty hours, twelve hours later, there were definite trabeculae which were laid down as appositional bone, and there was a complete layer of appositional bone apposed to the cortex and trabeculae extending outward from this. This was present at sixty hours in both the controls and in the cortisone-treated animals. We were amazed at how much difference the medullary pin made in the rapidity, probability, and uniformity of union.

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RUPTURE AND HERNIA OF THE TIBIALIS ANTERIOR MUSCLE

BY TAGE HØLUND, M.D., RANDERS, DENMARK

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Rupture of the tibialis anterior muscle is an infrequent occurrence. In 1947, Moberg collected four previously recorded cases and reported four cases of his own, but these eight cases were all ruptures of the tendon where it crosses the ankle joint. In spite of a careful search of the literature, no report of rupture of the belly of the tibialis anterior has been found. Rupture of this muscle in its contractile portion must, therefore, be considered to be extremely rare.

Muscle hernia of the tibialis anterior is more common. A number of cases have been reported, notably by military surgeons during the last decade. Most of these cases are of the so-called constitutional type,—that is, small, multiple, "spontaneous", often symmetrical herniae [3, 4, 5, 10, 12, 14, 15, 17, 19, 20], whereas larger solitary traumatic herniae are less frequent [7, 8, 9, 12, 15, 19].

REPORT OF A CASE

A seaman, aged forty-two years, had been injured during the unloading of a ship two months before admission. To avoid a falling packing case he had turned his body in such a way that the weight of the body was placed mainly on the right leg which rested on the fore part of the foot, while the heel was free of the deck and the knee was semiflexed. The edge of the case hit the lateral side of his leg, roughly midway between the malleolus and the knee. Pain and swelling at the site of the blow developed. He was treated at home for a fortnight with bed rest and compresses, and later with massage; but as difficulties in walking persisted and an intumescence developed on the leg, the patient was ultimately admitted to the hospital.

Physical examination revealed a healthy, strong-bodied man, walking with a limp in the right leg and with a tendency to "drop-foot".

On the middle of the anterolateral surface of the right leg, there was a soft-part swelling which increased in size and tension on dorsiflexion of the foot. Proximal to the swelling there was a distinct defect in the tibialis anterior muscle, but no fascial defect could be demonstrated.

Under spinal anaesthesia, a large curved incision was made proximally and laterally to the intumescence. The skin was mobilized and retracted. A complete rupture of the belly of the tibialis anterior at the juncture of its proximal and middle thirds and a fascial defect, measuring eight by three to three and five-tenths centimeters, with a corresponding herniation of the distal part of the muscle were found. All scar tissue was excised and the muscle was laid bare. A musculotendinous flap was cut in the middle of the aponeurosis with the base proximally (Fig. 1, *a*, *b*, and *c*). This flap was turned 180 degrees upward and sutured to the proximal muscle stump and the bone by means of fishgut. The muscle tissue was closed with interrupted catgut sutures (Fig. 2).

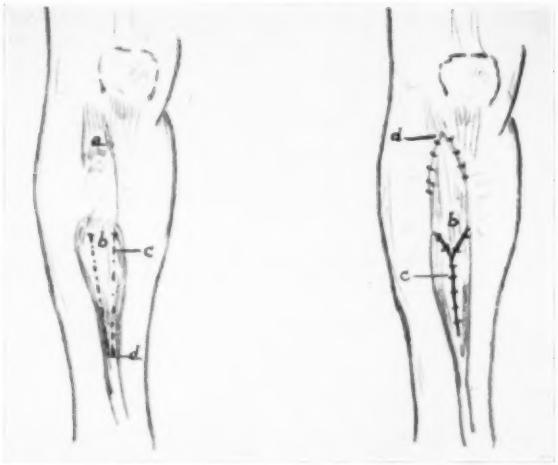

FIG. 1

FIG. 2

Fig. 1: *a*, proximal muscle stump; *b*, distal muscle stump. The dotted line *c-d* indicates the cutting of the muscle flap with base at *b*.

Fig. 2: The muscle flap *b-c-d* turned 180 degrees upward around a transverse axis at *b*. The apex of the flap (*d*) is sutured to the origin and proximal stump (*a*) of the tibialis anterior.

* Director: H. Krieger Lassen, M.D.

The large fascial defect was then repaired with a strip of fascia lata, measuring twelve by four centimeters, transplanted to the site and fixed by fine silk sutures. Finally, the skin was sutured with fishgut, and a circular plaster cast was applied to the leg and foot.

Apart from a slight necrosis at the distal margin of the wound due to the formation of a hematoma under the skin flap, primary healing was obtained. The plaster cast was removed three weeks later and exercise of the ankle joint was commenced; weight-bearing was allowed after six weeks.

A follow-up examination six months after the operation showed good function of the tibialis anterior. There were no signs of recurrence of the muscle hernia, and the gait was normal.

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DISCUSSION

Treatment of Non-Union in Fractures with Infection

(Continued from page 590)

but in the two cases in which we were unable to control the infection completely, we did go ahead with the bone-grafting procedure. I think the main point to be stressed is that when a compound fracture which is grossly infected is brought to your attention, the infection must not be neglected. I believe particular attention should be directed to controlling that infection before proceeding with bone-grafting.

As for transplantation of the fibula, this was done in two cases before iliac-bone grafting was done, and both failed to secure union. However, transplantation of the fibula when it will improve circulation in the tibia is certainly not to be condemned and can be used, I feel, in conjunction with the cortical grafting.

THE INFANT'S PERSISTENT THUMB-CLUTCHED HAND

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The purpose of this paper is to present and discuss eight cases of aplasia or hypoplasia of hand tendons. The principal tendon considered is the extensor pollicis brevis, and the resultant deformity consists in flexion of the thumb into the palm of the hand. The characteristic of this deformity is that the first metacarpal is held in abduction and the proximal phalanx is flexed forward and partially subluxated. Another common feature is the ulnar deviation of the hand. As frequently happens in congenital anomalies, these patients presented other congenital deformities, such as clubbed feet and dislocated hips.

Few reports can be found in the literature which describe absence or anomalies of tendons. Barsky, in his comprehensive paper on anomalies of the hand, stated that he had one case of absence of the long extensors to both thumbs. Zadek reported one case and Miller reported two cases. Kirklin and Thomas, in their article on tendon transplantation, mention that in tendon transplantations to obtain opponens action the extensor pollicis brevis may be used as a means of supplementing the motor power of a flexor tendon; they point out, however, that this tendon is sometimes absent. The tendon should therefore first be located and recognized. They also point out that the tendon may be very weak in some cases.

The two most commonly accepted views on the cause of congenital malformations are the hypothesis that they are a form of atavism and the theory which holds that they are due to a fault in the genes. In support of the theory of atavism we have Bunnell's statement that the extensor pollicis brevis is found "only in man and some gorrillas". On the other hand, the fact that six of the eight patients reported here were related to at least one other member of this series supports the theory of a defect in the genes. Seven cases in this series occurred within two generations of one family, and in the other case the family had a known history of the deformity for three generations.

Before considering the deformity which is present in these cases, we should first review the anatomy of the extensor tendons of the thumbs. The three main muscles involved are the extensor pollicis longus, the extensor pollicis brevis, and the abductor pollicis longus. The main function of the abductor longus is to stabilize the first metacarpal for the phalanges to act upon and to aid in flattening or pulling the thenar eminence out of the palm. In its attachment to the first metacarpal, it pulls the thumb in the dorsal and lateral direction and on continued action helps to extend and abduct the wrist. Primarily, the extensor pollicis brevis extends the proximal phalanx, and the extensor pollicis longus extends the distal phalanx. They both work together in extending the thumb.

As Bunnell has pointed out, when function of the extensor longus has been eliminated, the distal phalanx cannot be extended; to a slight extent this also weakens the extensor function at the metacarpophalangeal joint, which is primarily supplied by the extensor pollicis brevis. The chief function of the extensor pollicis brevis is to extend the metacarpophalangeal joint. It supplements to a lesser degree the long abductor. The long extensor, when not supported by the short extensor, has very little action on the metacarpophalangeal joint and, when the short extensor is absent or weakened, the characteristic deformity—that is, the thumb-clutched hand—appears.

Duchenne observed that "the paralysis of the short extensor of the thumb is more disturbing for use of the thumb than paralysis of the long abductor of the thumb, because this is followed by a turn of the thumb into the palm of the hand due to the predominant action of the flexors of the proximal phalanx".[2]

FIG. 1

Case 1, A. E. G. May 2, 1951. Photographs made before operation.

As has been said, the long abductor of the thumb plays an important part in abducting and extending the wrist. Similarly, the extensor tendons in their continued action help in abducting the wrist or maintaining the hand and wrist in its normal position. The absence or weakness of these tendons could result in the ulnar deviation seen in most cases.

The reports of cases in the literature all describe the absence of the long extensor; we feel that in one of these[7], judging from the photographs, an error was made in interpreting the cause of the deformity. An absence of the long extensor would have resulted in a flexion deformity of the distal rather than the proximal phalanx as illustrated. The cases reported in this paper present either agenesis of the long extensor or a rudimentary short extensor.

OPERATIVE PROCEDURE

The use of a tourniquet facilitates the operation. An incision is made over the dorsum of the wrist and the two extensor tendons to the index finger are identified. The extensor indicis proprius is usually the deeper of the two and is located more to the ulnar side. A longitudinal incision is made over the lateral aspect of the proximal phalanx of the index finger and the extensor mechanism is identified. The two tendons are fairly well fused in this area, but usually a dividing area can be found and the tendon can be split into its two portions. Pulling on the proximal portions identifies the part belonging to the common extensor group. The tendon of the common extensor is separated with tendon strippers and, after being cut as far distally as possible, it is brought out through the proximal incision. Another incision is then made over the base of the proximal phalanx of the thumb. The extensor pollicis longus is retracted to one side and a V-shaped tunnel is made dorsolaterally through the base of the proximal phalanx. Care should be taken to place the tunnel distal to the metaphyseal plate. A subcutaneous tunnel is then made from the proximal incision to the thumb incision and the cut tendon is pulled through it. The distal end of the tendon is then threaded through the tunnel in the bone and sutured back on itself; this is done by braiding the split end of the tendon back through the part of the tendon just outside of the tunnel. A plaster cast is applied for immobilization for three to four weeks; an elastic-webbing splint is then applied to maintain abduction (Figs. 9-A and 9-B) and active muscle training is started.

CASE REPORTS

CASE 1. A. E. G. was born June 12, 1950, of Chinese, Filipino, and Guamanian descent. His mother is E. S. (Case 6 in this report), with a similar condition. The patient had both thumbs flexed into his palms at

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2, A. G. July 18, 1950. Photograph made before operation.
Fig. 2-B: Photograph made September 18, 1950, after the first operation. The deformity recurred; after the condition had been correctly diagnosed, a successful tendon transplantation was performed on April 5, 1951.

the metacarpophalangeal joints. There was ulnar deviation of the hands (Figs. 1). He also had a calcaneovalgus position of both feet. The treatment of his hand condition with splinting was started on July 15, 1950, and was continued until February 12, 1951, when the tendon anomaly was recognized and he was admitted to the hospital for surgery. On May 31, 1951, the extensor communis indicis tendon was transferred to the base of the proximal phalanx of the right thumb. On July 12 1951, a similar procedure was carried out on the left hand. At the time of surgery the thumbs were held out from the flexed position by the transferred tendon. Both thumbs were held in a plaster cast for immobilization for four weeks, after which an elastic splint of the type shown in Figures 9-A and 9-B was used. This he has continued to wear. A month or six weeks after operation there was already evidence of some extensor action and the thumbs were held out of flexed position by the transplanted tendon.

CASE 2 (Figs. 2-A and 2-B). A. G. was born January 25 1948, of Chinese, Filipino, and Guamanian descent. She was the sister of A. E. G. (Case 1), their mother being E. S. (Case 6). Her deformity in infancy was marked; all her fingers were held in a position of flexion. This suggested weakness of all the extensor tendons. She was given pads and splints, and stretching exercises were advised; this improved all of the fingers except the thumbs. The left thumb was improved more than the right. There was marked ulnar deviation of both hands. On the assumption that the pathological condition was in the soft tissues on the flexor surface of the thumb, a tenotomy of the flexor pollicis brevis and a full-thickness graft to the flexor aspect of the right thumb was performed on July 20, 1950. She wore a splint until February 12, 1951, without any success. On April 5, 1951, after the condition had been recognized, the common extensor to the index finger was transferred to the base of the proximal phalanx of the thumb. Her hand was kept in plaster immobilization for four weeks; after this she wore an elastic type of splint. Function of this transplanted tendon slowly developed, but the patient had to wear the elastic splint for several months. It is believed that ultimate good function can be expected.

CASE 3. B. G. was born August 18, 1949. She is of Filipino, Spanish, Chinese, and Negro descent; her mother was A. S. (Case 4). Besides the thumb deformities she had a calcaneovalgus deformity of both feet. Both hands were in ulnar deviation (Fig. 3). On November 16, 1950, a full-thickness skin graft was applied to the flexor aspect of the right thumb, and on January 4, 1951, a similar procedure was performed on the left thumb. Plaster splints were applied to hold both thumbs in an abducted position, but the results were unsatisfactory. On February 21, 1951, the fasciculus of the common extensor of the index finger was transferred to the base of the proximal phalanx of the left thumb. On March 29, 1951, the same procedure was performed on the right thumb. During this procedure the tendon of the extensor digitorum communis to the

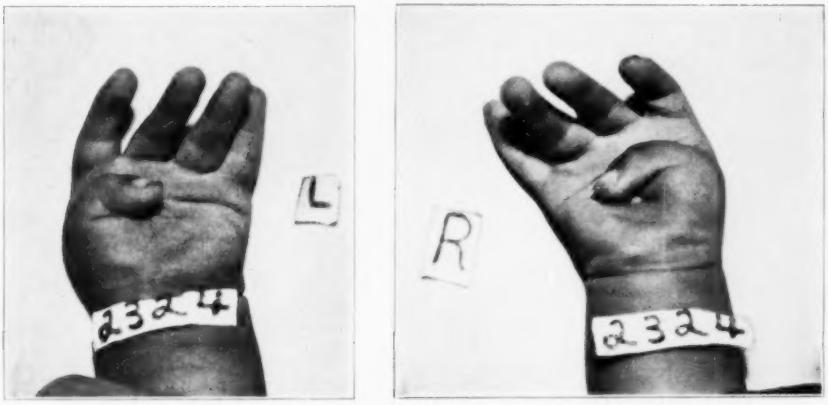

FIG. 3

Case 3, B. G. October 4, 1950. Photographs made before operation.

index finger broke as it passed through the tunnel in the proximal phalanx of the thumb and a free tendon transplant of the palmaris longus was used. The same type of postoperative immobilization was used as in the preceding case. Active extension in both thumbs was demonstrated when the patient was last seen.

CASE 4. A. S., mother of B. G. (Case 3), was born June 16, 1930, of Chinese and Filipino descent. Besides the deformity of her hands and thumbs (Fig. 4), she had a bilateral club-foot deformity. This patient and the following two were sisters and had the same parents. Their living conditions were poor, as the father's earning power was reduced by invalidism (tuberculosis). As a child, the patient had had no treatment except exercises for her thumbs, which, however, remained flexed in the palms of her hands. Examination of her hands showed a double abductor longus tendon which was very small, especially on one side. She had only one extensor tendon—that to the index finger on the right hand. The extensor tendons to the third and fourth fingers of both hands were displaced ulnarward. All her flexor tendons appeared contracted.

CASE 5. B. S. was born December 3, 1927. She was a sister of A. S. (Case 4) and E. S. (Case 6). Besides the hand deformities, she had a congenital dislocation of her left hip, which had been treated. Her thumbs had never been treated except by exercises when she was a child; they remained flexed at an acute angle in the palms of her hands. She also has abnormalities of other tendons to the fingers as seen by the deformity in Figure 5.

CASE 6. E. S. was born November 29, 1926. She is a sister of the two previous patients. When she was a child her thumbs were treated with exercises. She also showed a deformity of the ring and little fingers of both hands, associated with malformation of tendons (Fig. 6). This patient has not yet been operated upon.

CASE 7. G. A. was born March 19, 1943, of Hawaiian, Chinese, and Portuguese descent. He had the deformity bilaterally, but the right hand was considerably worse than the left (Fig. 7). On the assumption that a tight flexor band was causing the deformity, an incision was made on the flexor aspect of the left thumb on March 20, 1946, and on the right thumb on March 22, 1946. On October 5, 1950, a skin graft was applied to the base of the flexor aspect of the right thumb and lengthening of the flexor pollicis longus was carried out. He still has the deformity on the right, although it is somewhat improved, and his parents have been advised to have the extensor tendon procedure performed. To date they have not consented to this operation. The left thumb, in which the deformity has never been severe, has improved. This patient's great-grandfather, grandmother, and sister had the same condition. The sister also has evidence of other tendon anomalies in her hands.

CASE 8. B. J. was born December 26, 1946, of Chinese and Filipino descent. Her main deformity was in the left middle finger, which she could not extend at the metacarpophalangeal joint (Fig. 8). There was also some weakness in the extensor mechanism of both thumbs. There was some ulnar deviation of both hands. The extensor of the right index finger appeared especially weak. This child also had bilateral club-foot deformity. On April 19, 1950, the flexor aspect of the left middle finger was explored. The superficial tendon

was not identified, but the profundus tendon was lengthened. The deformity was still not corrected and on April 5, 1951, after the true situation was finally recognized, surgery was performed with the idea of correcting the extensor abnormality. The extensor tendon did not appear to lie in its normal position over the meta-

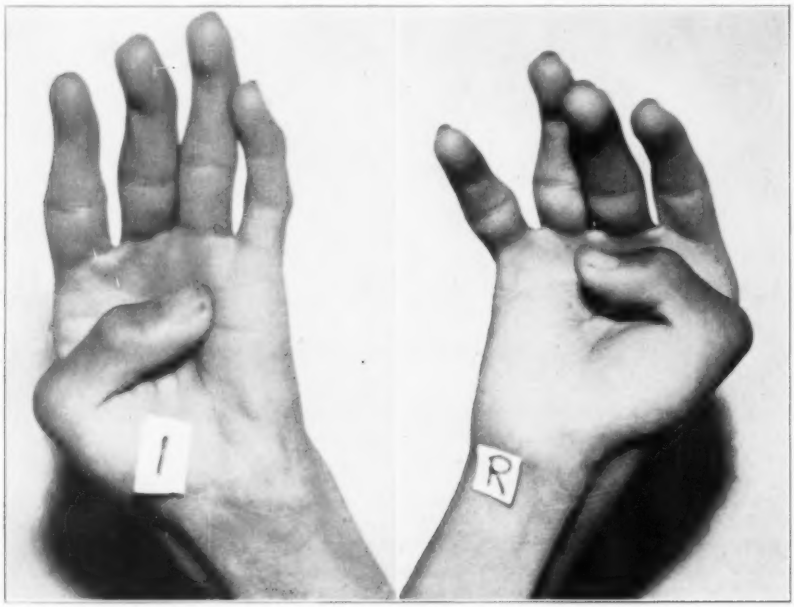

FIG. 4
Case 4, A. S.

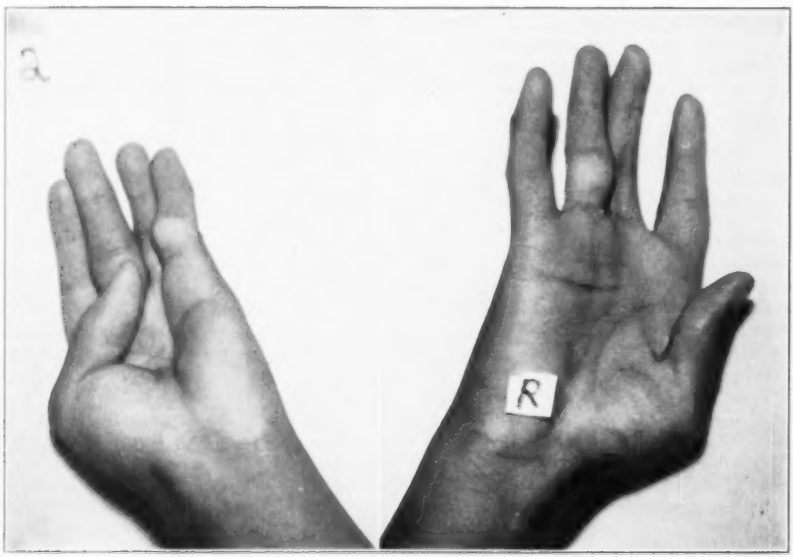

FIG. 5
Case 5, B. S.

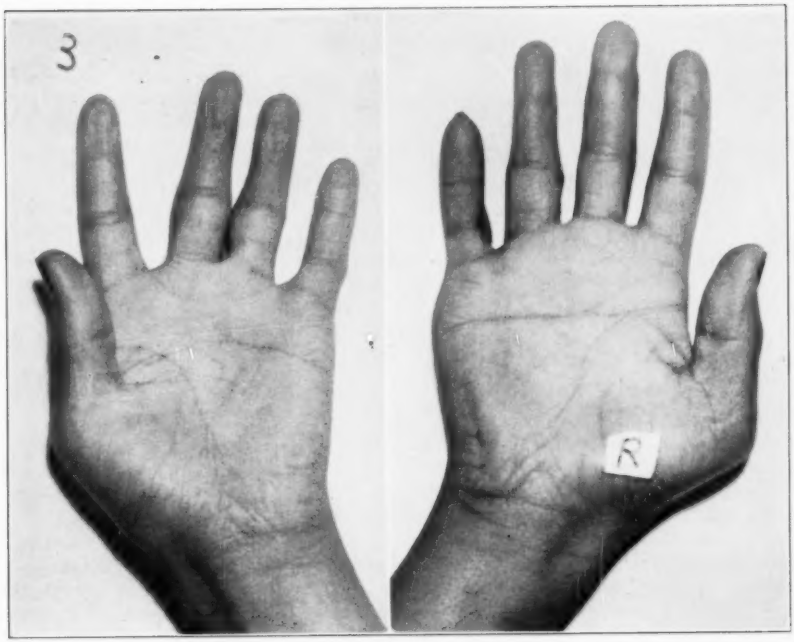

FIG. 6
Case 6, E. S.

FIG. 7
Case 7, G. A.

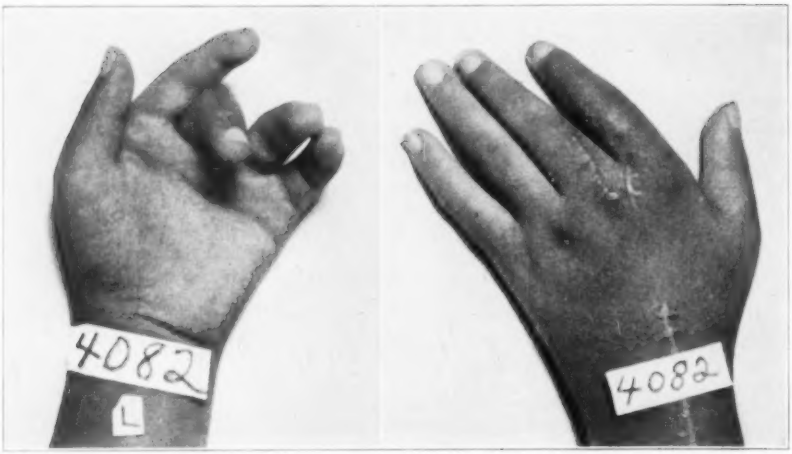

FIG. 8-A FIG. 8-B

Fig. 8-A: Case 8, B. J. S. Preoperative photograph made on April 2, 1951.
Fig. 8-B: Postoperative photograph made May 15, 1951.

carpophalangeal joint and the extensor mechanism. It appeared to be displaced to the side of the joint. The fasciculus of the extensor tendon to the index finger was transferred to the third finger. A splint holding this finger in extension is being used and the finger appears to be holding its good position. Active extension is present at the metacarpophalangeal joint.

DISCUSSION

Evaluation and interpretation of tendon malformation in infants and small children is difficult. Similarly, the results of the tendon transplantations will take a few years to evaluate. In these children the results following surgery, early as they may be, have been

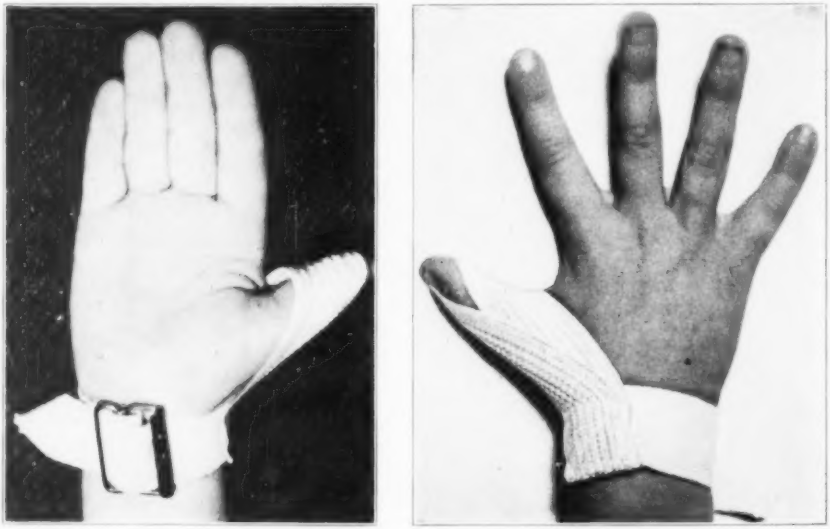

FIG. 9-A FIG. 9-B

Thumb splint used after the operation.

very encouraging. The thumbs are being held in abduction and extension out of the palms of the hands by the simple elastic-webbing abduction splint. Some active extension is evident. As can be seen from the case reports, the deformity in these patients was at first considered to be a superficial anomaly over the flexor aspect of the thumb. Surgical procedures were used to correct these, but the results were not satisfactory. One of us (J. W. W.) then interpreted the malformation as being mainly an absence or weakness of the short extensor of the thumb, and the results following surgery for that condition have been satisfactory.

A satisfactory splinting arrangement is used in all of these cases. This is an elastic thumb spica consisting of webbing with a buckle around the wrist and an elastic strap sewed to it in a loop, which holds the thumb in abduction and extension (Figs. 9-A and 9-B). Since all the patients operated on had had splinting previous to the surgery with only temporary benefit, it is evident that the splinting alone is not enough to maintain the position.

There is definite evidence that some tendons may be hypoplastic or rudimentary, and it is felt that with proper splinting and exercises they can be strengthened without surgery. If there is some weak action of the tendons, or evidence that the deformity is less severe, surgery may not be necessary. Surely conservative treatment with exercises should have a real trial. When the deformity is marked, a weakened tendon can be greatly strengthened by a tendon transplant.

It is also noted that some of these patients demonstrate weakness or anomalies of the tendons to the other fingers. This is seen particularly in the hands of these patients' mothers who have had no surgical treatment. The extensor tendons of some of the mothers' hands appear to lie displaced to one side of the metacarpophalangeal joint; this may be associated with the ulnar-deviation deformity. None of the mothers have yet decided to have anything done surgically, but all have disability and complaints.

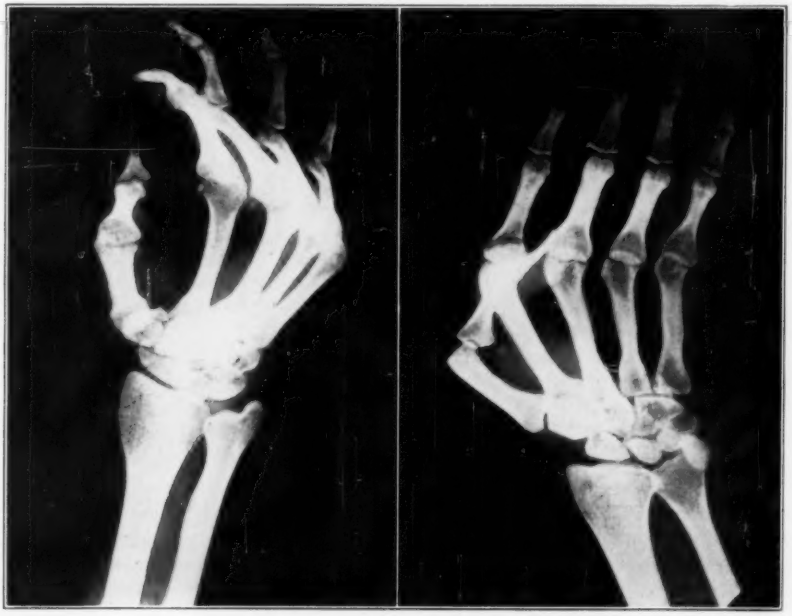

FIG. 10

Roentgenograms of the hands of an adult relative of Case 8. Deformity of the metacarpophalangeal joint is evident.

The treatment of patients with anomalies of tendons depends on clear-cut interpretation of each tendon malformation. If the tendon is absent or if there is marked deformity and no response to conservative treatment, some form of tendon transplantation is indicated. Miller, in discussing his patients, reports that he treated both by arthrodesis of the metacarpophalangeal joint. These were adults and probably had considerable joint deformity, so that attempts to get mobility would probably not be successful. This is demonstrated in Figure 10, a roentgenogram of one of the adults' hands, which shows definite deformity of the metacarpophalangeal joint. As regards the procedure to supply or reinforce this deficient short extensor of the thumb, it is best to employ another tendon activated by a normal muscle rather than to employ a free tendon graft. The index finger has two tendons, and as the extensor indicis proprius is the more specialized of the two, it was believed that the tendon from the common extensor muscle could more appropriately be used.

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CHONDROMALACIA FABELLAE

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On occasion it is a difficult task to determine the cause of internal derangement of the knee joint. The purpose of this report is to present two instances of internal derangement of the knee joint caused by a pathological lesion of the fabella, which the authors have designated chondromalacia fabellae.

The fabella, which means "little bean", is the sesamoid bone of the gastrocnemius muscle. The incidence of the fabella in the adult knee joint has been reported in the literature [3] as varying from 10 to 20 per cent. When present, the fabella is usually found bilaterally, on the anterior gliding surface of the lateral head of the gastrocnemius. Sutro, Pomeranz, and Simon and Heydemann have described rare instances of a fabella within the medial head of the gastrocnemius. According to Pfitzner the fabellae are constantly present both in the lateral and in the medial heads of the gastrocnemius muscles in rats, cats, and other animals. In these animals one or two additional sesamoid bones may be present in the popliteus muscle. The fabella is cancellous in structure and its diameter varies from five millimeters to two centimeters. The free surface of the fabella is covered by smooth articular cartilage. The remaining portion of the bone possesses no periosteum and is invested by the fibrous tissue of the gastrocnemius. On roentgenographic examination the contour of the fabella appears to be either semilunar or pyramidal in shape in

FIG. 1

FIG. 2-A

Fig. 1: Case 1. Lateral roentgenogram of the left knee joint, made June 30, 1950, showing a pyramid-shaped fabella and slight hypertrophic spurs of the patella.

Fig. 2-A: Case 2. Lateral roentgenogram of the left knee joint, made August 24, 1951, showing a semilunar fabella.

the lateral view and somewhat circular in the anteroposterior projection. Pathological changes of the fabella such as fracture [5] and osteochondritis [2] have been previously described.

Despite the fact that neither of the two patients to be reported gave a history of trauma, it is possible that the cumulative effects of daily activity may play an important role in the formation of the degenerative changes found in chondromalacia fabellae.

CASE REPORTS

CASE 1. Mrs. A. A., aged sixty-four, was first seen on September 18, 1950. She complained of pain in the left knee, intermittent for eight years and continuous for ten months. The pain was confined to the posterolateral aspect of the left knee joint. The patient had been treated elsewhere by medication, several courses of physical therapy, and by a plaster cylinder for the left lower extremity without relief of pain.

On examination the patient appeared to be in good general health. She walked with a slight limp on the left side. There was a complete range of motion of the left knee joint. Forced motions were painful at the extremes of flexion and extension. There was atrophy of the left thigh amounting to three-quarters of an inch; no swelling of the knee joint was noted. Tenderness was marked and definitely localized within a small, palpable bony mass, the fabella, on the posterior aspect of the left knee joint. Passive motion of the fabella on the posterior aspect of the lateral femoral condyle was painful. The opposite (right) fabella was palpable, but tenderness could not be elicited. Roentgenographic examination of the left knee joint (Fig. 1) showed minor hypertrophic changes of the patella. The fabella was somewhat pyramidal in shape. There was no roentgenographic evidence of osseous involvement of the fabella.

FIG. 2-B

Fig. 2-B: Photograph of specimen, showing the area of erosion in the central portion of the articular surface of the fabella.

Operation was performed on October 5, 1950. The central portion of the articular surface of the fabella was found to be degenerated and the subchondral bone was exposed. That portion of the articular cartilage of the posterior aspect of the lateral femoral condyle which had been in intimate contact with the fabella

had lost its normal bluish-white color and was softened and fibrillated. The fabella, together with the involved portion of the posterior articular cartilage of the lateral femoral condyle, was excised. The postoperative course was uneventful. The patient was last examined one year after operation and has remained free from pain.

Case 2. Mrs. L. M., aged sixty-one, was first seen on September 4, 1951. She complained of pain in the left knee joint. The pain had begun five months prior to her first examination. At the time of onset the pain was intermittent, but it gradually increased in severity, becoming aggravated by activity or after long standing. On occasion the patient had difficulty in moving the left knee joint. The pain was confined to the lateral half of the popliteal space and sometimes radiated to the left calf region. She had been treated elsewhere by physical therapy and medication without relief of pain.

On examination the patient was found to be in good general health, but walking with a slight limp on the left side. There was atrophy of the left thigh amounting to one-half inch. Motion of the left knee joint was complete, but forced extension was painful and the pain was confined to the lateral aspect of the popliteal space. Tenderness was sharply localized to the fabellar region. Passive motion of the fabella produced the same pain. Roentgenographic examination of the left knee joint (Fig. 2-A) revealed that the fabella was semilunar in shape and appeared to be approximately one-half inch distant from the posterior margin of the lateral femoral condyle. The fabella showed no roentgenographic evidence of pathological changes.

At operation on September 21, 1951, the articular surface of the fabella presented a central oval area of erosion (Fig. 2-B). The remaining portion of the articular surface of the fabella was slightly yellowish in color and was fibrillated. The articular cartilage of the posterior surface of the lateral femoral condyle presented no abnormality. The fabella was excised. The postoperative course was uneventful and, when the patient was last examined, on March 1, 1952, there had been no recurrence of the pain.

During the time between September 1950 and September 1951 when the two reported cases were examined, fourteen additional patients whose roentgenograms showed a fabella were seen in consultation. None of these fourteen patients presented the two characteristics which form the diagnostic criteria of chondromalacia fabellae, that is, localized tenderness over the fabella and pain on passive motion of the fabella. Ten of the fourteen asymptomatic patients were under thirty-five years of age.

SUMMARY

1. The degenerative changes of the articular surface of the fabella have been designated chondromalacia fabellae.

2. Localized tenderness and pain on passive motion of the fabella appear to be the chief diagnostic criteria.

3. Cure consists in the removal of the involved fabella.

4. At operation that portion of the posterior articular surface of the lateral femoral condyle which is in intimate contact with the fabella should be carefully inspected for evidence of degenerative changes. If such changes are present, this portion of the condyle should be removed.

5. It is hoped that increased experience with chondromalacia fabellae will help to reduce the percentage of error in the diagnosis of lesions of the knee joint.

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PERIOSTEAL CHONDROMA

A Distinctive Benign Cartilage Tumor*†

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This paper deals with a peculiar tumor which, although by no means rare, seems not to be generally recognized by surgeons and roentgenologists. Periosteal chondroma is a slowly growing benign cartilage tumor of limited size, which develops within and beneath the periosteal connective tissue and characteristically erodes and induces sclerosis of the contiguous cortical bone. As such, it must be clearly distinguished from osteocartilaginous exostosis (osteochondroma), as well as from solitary enchondroma. Thus far, we have encountered the tumor on hand and foot bones, as well as on large limb bones, such as the tibia and humerus. It seems altogether likely, however, that with broader experience we shall have occasion to observe the lesion in other sites as well.

Whatever its location may be, the tumor is composed of lobules of hyaline cartilage, not unlike an enchondroma. It tends to be more cellular, however, than does solitary enchondroma, and its content of plump cartilage-cell nuclei is likely to suggest a significantly active growth potential, although this impression is not borne out by what we know of the clinical behavior of the tumor. This paradox emphasizes once again that, in dealing with skeletal tumors (as with other neoplasms), one must clearly recognize that each neoplasm has its own particular set of criteria governing benignity or malignancy, which can only be determined empirically by clinical-pathological correlation in a significantly large group of relevant cases.

Our attention was first directed to this lesion by two hospital cases in which the tumor had developed on a finger phalanx and a metatarsal bone respectively. The roentgenograms of these tumors had been rather perplexing preoperatively, although from the specimens obtained at surgery it seemed clear that we were dealing with comparable instances of a unique cartilage tumor, apparently developing within the periosteum. This tumor obviously did not represent an enchondroma which had distended the cortex, since the interior of the affected bones was clearly uninvolved; nor did it represent an osteocartilaginous exostosis (osteochondroma), since the cortex, although modified, was not defective at the tumor site. When these cases were presented, by a happy coincidence, several of the orthopaedists on our attending staff recalled having operated upon patients with similar lesions within recent months. This additional material was graciously placed at our disposal, so that the present report is based upon a survey of six cases, all but one of which were observed within a period of a year.

In the light of our experience, it seems rather surprising that there should be scarcely any mention of this tumor in the literature under whatever name. In fact, the only clear-cut reference to it which we have been able to find is that of Mason who, in connection with a comprehensive survey of tumors of the hand in general, made brief mention of a periosteal chondroma developing on the proximal phalanx of a fifth finger. It is interesting that his designation of the tumor is precisely the one which we had adopted independently before we had had occasion to refer to his article. Another probable instance is the tumor illustrated by Roberts as an "eccentric chondroma" of a finger phalanx, although the

* Presented in part at the meeting of the Western Orthopedic Association, Portland, Oregon, October 1950.

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FIG. 1

FIG. 2-A

FIG. 2-B

Fig. 1: Roentgenogram of a periosteal chondroma developing on the upper portion of the shaft of the humerus of a twelve-year-old girl. This tumor was the largest of any observed and was also noteworthy because it eventually acquired a thin shell of periosteal new bone over its convexity. The patient had been first observed eighteen months previously, at which time she presented a somewhat smaller, gouged-out cortical defect, the interpretation of which was perplexing. The surgeon elected to do a block excision in this instance.

Fig. 2-A: Roentgenogram (lateral view) of a comparatively small periosteal chondroma, developing on the cortex of the upper portion of the shaft of the tibia of a four-year-old boy. The tumor itself was reflected merely in vague soft-tissue swelling; evident in the print is the sclerotized trough in which the tumor nestled.

Fig. 2-B: Roentgenogram (anteroposterior view) of the same lesion. If this view alone had been examined, the tumor might conceivably have been mistaken for a central tumor and specifically for an enchondroma.

The case came to clinical notice because the child's mother became concerned over a slowly enlarging lump below the knee. Block excision was done in this case also. Follow-up roentgenograms made six months later showed complete reconstruction of the affected cortex.

writers find his explanation of its pathogenesis unconvincing. This cartilage tumor had produced a somewhat sclerotized declivity in the proximal portion of the middle phalanx of the affected finger and was delimited peripherally over its ovoid convex contour by a delicate shell of periosteal new bone. On the other hand, the case reported by McWhorter, which Mason cited as also being relevant, seems hardly acceptable as such but appears rather to represent an unusual chondrosarcoma, developing in the soft parts of a thumb, superficial to the periosteum. This particular neoplasm grew rapidly following an injury and, within a few months, came to encase the articular bone ends comprising the metacarpophalangeal joint. The writers have been unable to find any pertinent reference to lesions developing on large limb bones, comparable to those illustrated in Figures 1, 2-A, and 2-B.

CLINICAL FEATURES

Age and Sex Incidence

In the group of six cases constituting the basis for this discussion, both male and female patients are represented. Two were young children, while the remainder were adults,

FIG. 3

FIG. 4

FIG. 5-A

Fig. 3: Roentgenogram (enlarged) of a periosteal chondroma which had eroded the cortex of the palmar aspect of the middle phalanx of an index finger and induced striking reactive sclerosis. The patient, a woman, sixty-four years old, had complained of a slowly enlarging swelling for four years. There was pain on motion and moderate limitation of flexion.

Fig. 4: Roentgenogram (enlarged) of a tumor which, over a period of ten years, had produced a markedly sclerotized declivity in the proximal portion of the proximal phalanx of an index finger. Motion of the affected finger was painful, but was not appreciably limited. The radiopaque stippling within the lesion proper reflects focal ossification of tumor cartilage.

Fig. 5-A: Roentgenogram (enlarged) of a comparable lesion in the distal end (the "bunion area") of a first metatarsal bone. The patient, a man, twenty-two years old, had complained of localized tenderness, but there was no palpable swelling. At surgery, the tumor was shelled out of its hollow in the cortex and the extremely hard base of the lesion was curetted. The radiopaque foci within the tumor reflect focal calcification.

both young and old. These factors, therefore, appear to have little significance in the matter of differential diagnosis.

Localization

As noted, we have observed the tumor thus far only on one or another of the bones of the foot or the hand (including the carpus), and in relation to the cortex of large limb bones. Specifically, two instances were encountered on finger phalanges, one on a carpal navicular bone, one on a metatarsal bone, and one each in apposition to the upper shaft of the tibia and humerus respectively.

Complaints

The major complaints directing attention to the tumor and to the necessity for its roentgenographic examination were increasingly perceptible swelling of the affected site, pain on motion of the part, or both, particularly when the lesion was situated in proximity to a joint. It should be emphasized that the tumor tends to develop quite slowly and insidiously, often requiring a number of years to attain appreciable size. Thus, in one instance in which the tumor was on an index finger, the patient had been aware of a localized swelling for as long as ten years before he sought surgical treatment; in another comparable instance, the swelling had been present for over four years. It is noteworthy also that there was no indication in any of the case histories that trauma had played a significant role in the development of the tumor.

FIG. 5-B

Photograph (enlarged) of the specimen removed in the case illustrated in Fig. 5-A. The tumor was adherent to the periosteum; it presented a glistening, white, bosselated surface.

CHARACTERISTIC ROENTGENOGRAPHIC PICTURE

At the site of the lesion one observes in the appropriate view a comparatively small, peculiar trough-like hollow or declivity in the cortex (Figs. 1, 2-A, and 2-B). The base of this semilunar hollow consists of sclerotized cortical bone, apparently reflecting reaction to slow pressure erosion. Of the tumor itself, which is responsible for these changes, beyond a vaguely defined soft-tissue shadow one observes only such focal areas within it as happen to be sufficiently calcified or ossified for visualization. In other views, if the projection of this lesion and its depressed, sclerotized cortical base is superimposed on that of the shaft of the affected bone, one may gain a false impression of a central tumor of rounded or ovoid contour, suggesting an enchondroma (Fig. 2-B). Ordinarily, the peripheral contour of the tumor is not visible, although in one instance (the one in the humerus) this eventually became outlined by a delicate convex shell of periosteal new bone (Fig. 1).

If one is familiar, in general, with the roentgenographic appearance of periosteal chondroma, the picture in any given instance is likely to be sufficiently distinctive to strongly suggest the diagnosis, although otherwise it will probably be rather puzzling. This impression will be heightened if, as is sometimes the case, one observes irregular focal areas of increased density within the lesion nestling in the hollow of the eroded cortex, which indicates its probable cartilaginous nature (Figs. 3, 4, and 5-A). In dealing with instances of the tumor developing in relation to finger phalanges particularly, the observer must also consider, by way of differential diagnosis, the possibility of either a glomus tumor or a lesion of pigmented nodular tenosynovitis [1] (giant-cell tumor of tendon sheath, so-called) which has eroded the contiguous cortex, as it occasionally does.

PATHOLOGICAL FINDINGS

Gross Appearance

Whatever its particular location may be, periosteal chondroma is a circumscribed and somewhat lobulated growth (Fig. 5-B). It is well confined, at least over its convexity, by its investing periosteal connective tissue. In the instances observed, the tumors were found also to be somewhat flattened and rounded or ovoid in contour, and to range in size from about 1.5 to 3.5 centimeters in the greatest dimension. Actually, most of the specimens we encountered were comparatively small and at the lower limit of the range indicated. They were noted to be rather firm or rubbery, and whitish or bluish in color, so they could be readily identified as cartilage growths.

As noted, the tumor develops in close apposition to the cortex of the affected bone, nestling in a semilunar hollow which it has apparently created by gradual pressure erosion. In the instances in which the growth was shelled out of its bed, it was observed by the surgeon that the base of this cupped-out area was composed of rather smooth, very hard, sclerotized cortical bone, as one might expect from the roentgenographic appearance. This bone did not appear to be infiltrated by tumor cartilage, in the gross at least.

Microscopic Features

On microscopic examination (Figs. 5-C, 5-D, and 5-E), one observes that the tumor

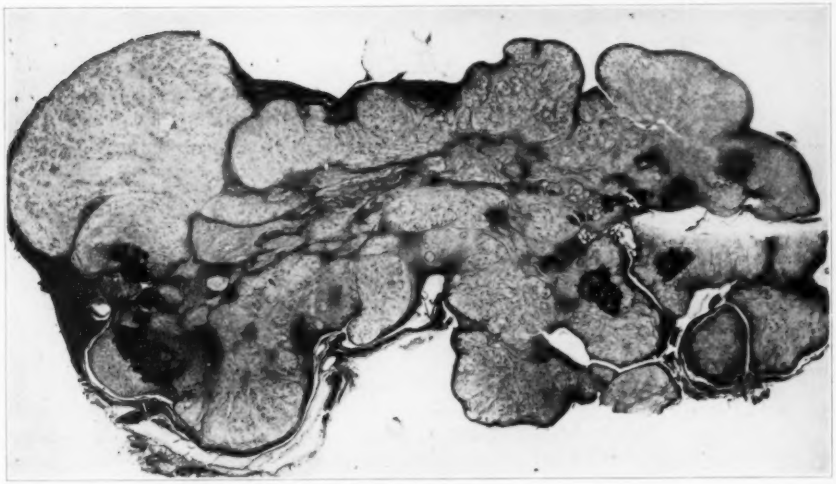

FIG. 5-C

Low-power photomicrograph (× 11) of a section of an entire specimen, showing its topography. The tumor is invested by periosteal fibrous connective tissue and is composed of lobules of hyaline cartilage, some of which exhibit focal calcification.

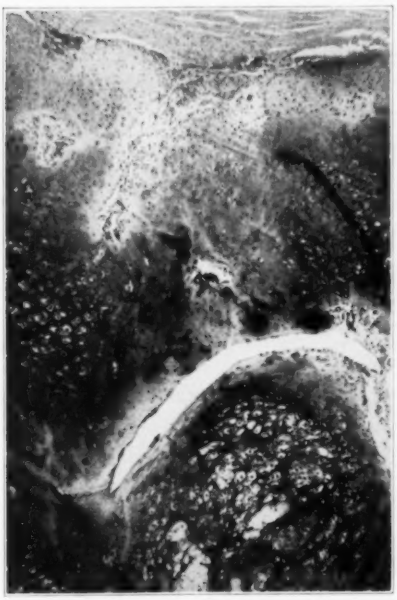

FIG. 5-D

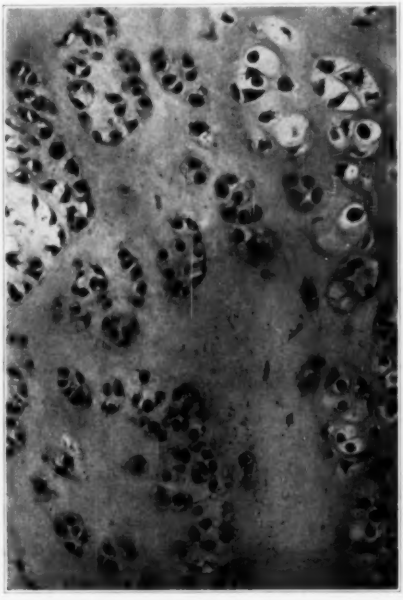

FIG. 5-E

Fig. 5-D: Photomicrograph (× 27.5) of a representative field from the periphery of the tumor.

Fig. 5-E: Higher magnification of a representative field of the tumor (× 175) showing its cytological details. The cartilage-cell nests are somewhat more compact than they would be ordinarily in a solitary enchondroma, and some of the nuclei are relatively plump. In the light of the clinical behavior of this particular neoplasm, however, these findings are not to be construed as indications of malignancy.

is composed of lobules of hyaline cartilage with more or less basophilic matrix; in so far as their general pattern is concerned, the cartilage-cell nests are not unlike those of an enchondroma [2] (Figs. 5-C and 5-D). In most of our specimens, these cell nests were considerably more prominent in relation to the matrix than one ordinarily observes in a solitary enchondroma. In fact, the cartilage cells in places, especially toward the periphery of the facets, were sufficiently compact and their nuclei were plump enough so that, if one applied to it the criteria for malignancy pertaining to enchondroma (Fig. 5-E), he might be inclined to regard the growth as an early chondrosarcoma. In this connection, however, it is important to bear in mind that one must gauge the seriousness of a tumor by what it actually does, rather than by any preconceived cytological standards unrelated to its known clinical behavior. Suffice it to state that our follow-up observations to date do not afford any basis for taking a serious view of the relative cellularity of periosteal chondroma.

In some of the older lesions particularly, one may observe some collagenization of the matrix and focal calcification of cartilage, as well as osseous transformation in places, although, on the whole, these are not prominent features. These secondary changes, when present, are likely to appear at the periphery of the cartilage lobules, in proximity to the numerous thin-walled blood vessels which are carried by the connective tissue of the capsule and its infoldings.

It is significant to note that, in several of the specimens, one could also observe within the (periosteal) connective-tissue capsule small focal areas of cellular condensation and chondroid metaplasia. The finding of such lobules of newly formed cartilage affords some insight into the manner in which the tumor probably has its inception.

Sections of the hollowed-out cortical bone constituting the bed of the lesion confirm the presence of reactive sclerosis, as noted in the gross specimen. In one of the available specimens excised *en bloc*, we encountered small inclusions of tumor cartilage within this sclerotized bone, although these had not penetrated deeply. On the basis of this finding, curettement of the underlying bone is recommended as a precautionary measure to guard against possible local recurrence.

TREATMENT AND PROGNOSIS

In the light of our experience with this neoplasm, the therapeutic procedure which seems indicated is conservative surgical extirpation. This is readily accomplished, as a rule, since the tumor is sufficiently small, firm, and circumscribed so that it can be removed intact from its bed without difficulty, although it may be adherent to the periosteum. In most instances it does not appear to be essential to do a block excision of the cortical bone surrounding the lesion. As noted, however, the surgeon would be well advised to thoroughly curet the resistant, sclerotized cortical bone constituting the base of the lesion, in order to remove any tumor remnants which may be present.

We are not in a position to comment upon the efficacy of roentgen therapy, since none of the tumors presented were so treated. *A priori*, however, we would be disinclined to advocate its trial, in view of the ineffectiveness of irradiation against cartilage tumors in general. Moreover, it scarcely seems justified to accept the known hazards of this modality in treating a benign neoplasm which can be readily cured by simple surgical removal.

Four of the tumors included in this series were treated in the manner advocated with uniformly satisfactory results. In the remaining two instances, block excision was resorted to, after which it was observed that the cortical defect filled in promptly, so that within six months the normal contour of the cortex was restored. Although none of the patients covered by this report have been followed for more than three years and most of them for only a year or two, there has been no indication of any tendency to local recurrence following surgical extirpation.

SUMMARY

Periosteal chondroma represents a distinctive benign cartilage tumor, apparently originating in the periosteum. This discussion is based upon experience with six cases, all but one of which were observed within a period of a year. We have encountered the tumor, thus far, on hand and foot bones, as well as on large limb bones, such as the tibia and humerus. It is a slowly growing neoplasm of comparatively small size, which develops within and beneath the periosteal connective tissue and characteristically erodes and induces appreciable sclerosis of the contiguous cortical bone. As such, its roentgenographic appearance has a certain distinctiveness which enables one to recognize the lesion, if he is familiar with it, and clearly to distinguish it from osteochondroma, as well as from solitary enchondroma.

The tumor may develop in children, as well as in adults. The symptoms usually referable to it are pain, gradual swelling, and local tenderness. The duration of symptoms in the cases observed ranged from a few months to ten years. Clinically, one finds a firm, generally small, slightly tender tumor which, if located near a joint, may produce some limitation of motion. At surgery, one observes a rubbery, firm, lobulated cartilage tumor, adherent to the periosteum. This is found to be partially nestled within the gouged-out underlying cortex, which is extremely resistant to curettage.

Whatever its localization, the tumor is composed characteristically of lobules of hyaline cartilage. Although its cartilage-cell nests are likely to be more compact then those of an enchondroma and its cell nuclei somewhat plumper, these cytological features are not to be construed as indications of aggressiveness or malignancy.

The treatment recommended in most instances is conservative surgical extirpation and curettement of the eroded, sclerotized cortical base. Block excision is feasible if the tumor has involved a long limb bone and is substantially larger than it is on a finger phalanx, for example. The results of treatment by either method were uniformly satisfactory. Although none of the patients covered by this report have been followed for more than three years and most of them for only a year or two, there has been no indication of any tendency to local recurrence following surgical extirpation.

NOTE: For the pertinent material in four of the cases constituting the basis of this discussion, the writers are indebted to Dr. Cozen, Dr. Ferguson, Dr. Hutter, and Dr. Urist, respectively.

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RUPTURE OF THE EXTENSOR DIGITORUM COMMUNIS TENDONS FOLLOWING SEVERELY DEFORMING FRACTURES ABOUT THE WRIST

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Although rupture of the extensor pollicis longus tendon following Colles' fracture has been well known for many years, only two cases of spontaneous tear of the extensor digitorum communis tendons have been reported in the literature. In these patients, reported by O. J. Vaughn-Jackson in 1948, the rupture resulted not from fractures about the wrist, but from osteo-arthritis of the wrist joint.

The following communication records two cases of rupture of the extensor digitorum communis tendons after fractures about the wrist. In one instance rupture occurred ten years after a malunited fracture of the semilunar bone. In the second case, rupture occurred seventeen years after an unreduced, malunited fracture of the distal end of the radius with dislocation of the distal end of the ulna.

CASE 1. A Puerto Rican male, twenty-two years old, was first seen twenty-four hours after an injury to the fourth finger of his left hand. He was working as a "stuffer" of boxing gloves, holding the glove in the left hand and inserting the stuffing with the right. While at work, he suddenly experienced a snapping sensation and sharp pain in the left wrist and in the dorsal aspect of the mid-region of the left forearm. Immediately following this he was unable to extend completely the fourth finger at the metacarpophalangeal joint (Fig. 1-A).

In 1941, ten years before the tendon injury, he fell while skating and sustained a fracture of the left wrist. As a result, there remained a prominence about two centimeters in diameter on the dorsum of the wrist, but functionally there had been no difficulty until the injury recorded above.

The roentgenogram demonstrated a most unusual fracture of the wrist (Fig. 1-B). The bone fragment had resulted from a fracture of the semilunar bone; it had become dislocated and attached to the dorsal lip of the distal end of the radius at an angle of about 45 degrees.

At operation the volar and distal free surface of the fragment was found to be lined with a fibrous articular cartilage and formed a pseudarthrosis with the remaining portion of the semilunar bone which had not been dislocated. This bone deformity was found to be in the direct line of the torn fourth extensor tendon and appeared to have gradually eroded the tendon until rupture occurred. The prominence was removed at its base with an osteotome. The ruptured fourth extensor tendon was found to be contracted and somewhat curled upon itself, so that the distal free end came to lie at the level of the mid-shaft of the fourth metacarpal bone. It was ensheathed in a thin, flat film of connective tissue which was continuous with the tendon sheaths of the third and fifth extensor tendons. The severed tendon had lost its normal color and consistency; it was a dull, dark grey, irregularly thickened, and without the flexibility of the normal tendon. The free distal end of

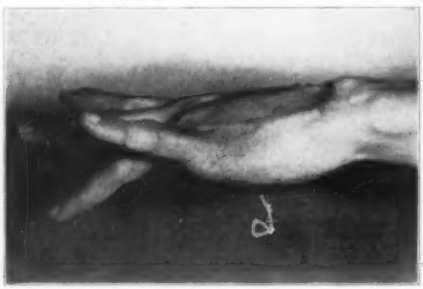

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. The dropped fourth finger and the prominence on the dorsum of the left wrist representing the fracture-dislocation of the semilunar bone are shown.

Fig. 1-B: Lateral-flexion roentgenogram showing fracture of the semilunar bone and attachment of one of the fragments to the dorsal lip of the distal end of the radius.

FIG. 2-A

FIG. 2-B

FIG. 2-C

Figs. 2-A and 2-B: Case 2. Antero-posterior and lateral roentgenogram of the right wrist, showing the malunited fracture of the distal end of the radius and dislocation of the distal end of the ulna.

Fig. 2-C: Photograph demonstrating the loss of extension of the third, fourth, and fifth fingers in the same patient. The dislocation of the distal end of the ulna and the malunited radius are also seen.

the tendon was dissected away from its abnormal attachments and, with the wrist and fingers in full extension, was sutured end to side and side to side to the third extensor tendon.

It was obvious at operation that the sharp edge of the dislocated fragment had subjected the fourth extensor tendon to continual trauma. The gradual process of attrition finally resulted in rupture of the tendon. It was found that the distal end of the tendon could not be approximated to the proximal end, because of the shrinking and retraction resulting from the degenerating process described above.

Stainless-steel sutures were used. A plaster-of-Paris bandage was then applied from the finger tips to below the elbow with the wrist and fingers in extension. This was worn for three weeks.

After seven weeks the patient returned to his occupation as a stuffer of boxing gloves, with complete function of the involved hand except for a lag of extension of the fourth finger amounting to 5 degrees.

CASE 2. A nurse, sixty-five years old, had fractured her right wrist in a fall while working in a sanatorium in 1932. A malaligned fracture of the distal end of the radius (Colles' fracture) with dislocation of the ulna resulted (Figs. 2-A and 2-B). Despite some restriction of motion, the patient had little difficulty for many years and was able to continue work at various nursing jobs.

In October 1949, seventeen years after the original fracture, the patient was attempting to lower a window which was stuck when pain and swelling suddenly developed in the right wrist; she found she was unable actively to extend the fourth and fifth fingers at the metacarpophalangeal joints. Motion at the interphalangeal joints was not affected. The pain and swelling persisted for several days and slowly decreased, but the loss of extension persisted. No surgery was advised at that time and she continued with her work.

In February 1950, she again experienced sudden sharp pain in the right wrist. This occurred while she was carrying a drum of sterile gauze weighing about fifteen pounds. This time the third finger was involved and she was unable completely to straighten this digit. Accompanying the inability to extend completely the third, fourth, and fifth fingers, there was also partial loss of active extension at the wrist joint itself, this motion being now possible to only 180 degrees.

On September 21, 1951, the dorsum of the right hand, the wrist, and the forearm were explored surgically. The distal ends of the torn extensor tendons to the third and fourth fingers were found lying together, embedded in scar tissue, at the level of the juncture of the proximal and middle thirds of the third metacarpal bone. They had evidently ruptured as a result of erosion, caused by their gliding back and forth over the abnormally prominent distal end of the fractured radius. These tendons were quite normal in color and texture, but were somewhat thinner than the extensor tendon of the index finger. The fifth extensor tendon (extensor

digiti quinti proprius), surprisingly enough, was intact. In the injury of October 1949 it had slipped ulnarward and palmarward, together with the extensor carpi ulnaris, over the large hump formed by the dislocated lower end of the ulna. Rupture of the annular ligament of the wrist, evidently at the time of fracture, had made this possible. These two tendons came to lie medially to the lower end of the ulna. Because of this unusual location, they lost their fulcrum at the wrist and hence their power to extend the fifth finger or the wrist. Before the operation it was believed that the fifth extensor tendon had also been ruptured.

The proximal end of the cut tendons could not be found. It may be that, since there was a considerable lapse of time between the actual laceration of the tendon and the operation, these tendons became adherent and bound down in the other extensor muscles. Because of this, it was necessary to use the extensor tendon of the index finger as the motor for the middle and fourth fingers.

The distal two-inch portion of the ulna was resected and the flexor carpi ulnaris was transplanted to the dorsum of the wrist on the ulnar side. The transplantation of the flexor carpi ulnaris was necessary because the extensor carpi ulnaris, while not ruptured, was dislocated to the ulnar side of the wrist and for many years had not functioned as an extensor. It was therefore thinned out, weakened, and atrophic, and at the time it did not seem that it could function adequately without some additional help. Furthermore, the extensors of the third, fourth, and fifth fingers had not been used to aid in extending the wrist for some time, so that mild drop-wrist resulted. Because of this general extensor weakness, it was felt that additional extensor motor power was necessary.

The two distal ends of the extensor tendons of the third and fourth fingers were then sutured into the index extensor tendon with the wrist and fingers in hyperextension. The fifth extensor tendon and the extensor carpi ulnaris were freed from their attachments in the soft tissues medial to the lower end of the ulna and were replaced in the dorsum of the wrist.

At present the patient is back in her old job preparing sterile dressings for the operating room. She uses her hand and wrist with much greater dexterity and less fatigue. Before the operation she had used only the thumb and index fingers; she now uses all five fingers. The range of motion at the wrist and fingers has increased, the wrist being extended to 15 degrees and the third, fourth, and fifth fingers to within about 20 degrees of the neutral position. The index and third fingers flex to within one-half inch of the palm, the fourth and fifth finger to within one inch of the palm. The grip is good and there is no pain at the wrist.

COMMENT

There is some similarity between rupture of the common extensor tendons and rupture of the extensor pollicis longus. The longest recorded interval between fracture at the wrist and rupture of the extensor pollicis longus is ten years[1]. One case of rupture of the extensor digitorum communis occurred ten years after the wrist fracture. In the other instance, seventeen years elapsed (after the fracture-dislocation of the wrist) before the first tear of the extensor tendon took place.

Trevor states that the extensor pollicis longus tendons observed at operation in his series showed evidence of swelling and discoloration indicating aseptic necrosis. In Case 1, there was definite evidence of degeneration with changes in color, consistency, and elasticity of the tendon that was torn. In Case 2, the ruptured tendons had become revitalized after being reattached in the subcutaneous tissues and, after some time, had assumed the appearance of normal tendons except for the fact that they were somewhat thinner.

It is interesting to note that only two cases of this injury had been found previously, and that these did not follow fractures about the wrist. On the other hand, over a hundred cases of rupture of the extensor pollicis longus tendon have been recorded[2]. Perhaps one of the reasons for the almost complete absence of reports on tear of the extensor digitorum communis is the fact that rupture of only one of these extensor tendons causes no great disability. The distal free end of the tendon eventually becomes reattached to the common extensor aponeurosis and only part of the extensor power is lost. Moreover, these ruptures occurred so long after the initial fracture that this may be overlooked as the etiological factor.

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SOME HISTOPHYSIOLOGICAL PROBLEMS PECULIAR TO CALCIFIED TISSUES *

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INTRODUCTION

The several kinds of connective tissue in the body all consist of two chief components: (1) *living* cells, and (2) *non-living* organic intercellular (also called extracellular) substances; the latter are produced by the cells and lie between and outside them.

A connective tissue which normally becomes calcified contains the same basic components as an uncalcified connective tissue,—living cells and non-living organic intercellular substance. It differs from an ordinary non-calcified connective tissue fundamentally only because its organic intercellular substance becomes impregnated with calcium salts.

It might be thought that, because the organic intercellular substance of connective tissue is non-living, little difference would be made if it became calcified. We shall see, however, that it does; it makes the nutrition, growth, repair, and grafting of the tissue both more difficult and more complicated than is the case in an uncalcified tissue. Indeed, it is the purpose of this paper to explain the peculiar difficulties imposed on the nutrition, growth, repair, and grafting of a tissue which are caused by the calcification of its organic intercellular substance. For our example of an uncalcified connective tissue we shall choose the dermis of the skin, and for a calcified tissue, bone. This paper, then, is designed to illustrate the differences between the processes of nutrition, growth, repair, and behavior on transplantation of skin and bone.

MECHANISMS FOR NUTRITION BEYOND THE CAPILLARIES

Food and oxygen are brought to the body tissues by arteries and released to the cells of the tissues through the thin walls of capillaries. It is to be appreciated that the great majority of the cells of the body do not live directly beside capillaries, but are separated from them by intercellular substances and other cells (Fig. 1); hence there must be some efficient mechanism *beyond the capillaries* by which food and oxygen can be transported from the capillaries to cells, and waste products from the cells to the capillaries. It is in association with this mechanism beyond the capillaries that many of the problems peculiar to calcified tissues arise. To discuss this matter, we shall first consider the mechanism that operates in a non-calcified tissue, the dermis.

Mechanisms in Dermis

Figure 1 is a diagram of a capillary lying in the intercellular substance of dermis close to the epidermis. Connective-tissue cells are scattered throughout the intercellular substance. There are three ways by which these cells, as well as the cells of the non-vascular epidermis above, can be nourished:

1. *By the circulation of tissue fluid:* It has been generally assumed that, in most body sites, tissue fluid, as a dialysate of plasma, is more or less continuously produced by the arterial ends of blood capillaries and just as continuously absorbed by the venous ends of blood capillaries and by the lymphatic capillaries. According to this view, tissue fluid circulates; this requires that the intercellular substances themselves be freely permeable to tissue fluid or, if they themselves be not, that they be riddled with clefts (Fig. 1) or passageways through which the tissue fluid can pass from one place to another.

* Read in part at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 22, 1951.

2. *By diffusion through tissue fluid:* Although the increased rate of lymph flow which occurs in certain kinds of oedema clearly illustrates that a circulation of tissue fluid can occur, there are many authorities who doubt that there is a very substantial circulation of tissue fluid in most connective tissues under normal conditions. Even if tissue fluid does not circulate, it could, however, if it bathes the intercellular substances, serve as a means for the diffusion of food and waste products between capillaries and cells. However, it is not even necessary for free tissue fluid to be present in the intercellular substance for diffusion phenomena to operate because, as is true of cartilage, the gels of the intercellular substance themselves can serve as a means of diffusion. This mechanism will now be discussed.

3. *By diffusion through gels:* The protein fibrous elements of intercellular substance (collagenic, reticular, and elastic fibers) are variously embedded in amorphous substances which the histologist through the years has called *ground* and *cement substances*. Over the past few years Meyer [8, 9] has intensively studied the chemistry of these latter two materials and, having shown that they are more of the nature of carbohydrates than of proteins, has termed them *mucopolysaccharides*. One distinction between different kinds is whether or not they are sulphated. Hyaluronic acid is the common non-sulphated kind and chondroitin sulphuric acid is a common sulphated kind. Hyaluronic acid can exist as a sol, as it does in aqueous humor or in synovial fluid, or as a gel, as it does in the ground substance of areolar tissue. In general, the gels formed by the sulphated types are firmer than those formed by hyaluronic acid; hence the sulphated types are often termed *cement substances*.

It would appear that there is a division of labor among the two chief components of intercellular substance, with the fibrous protein elements functioning chiefly for support and strength, and the mucopolysaccharides—although the cement substances also serve a supporting role—as a means by which diffusion can readily occur between capillaries and cells. Indeed, it seems very probable that this is a very important function of the mucopolysaccharides, and it is perhaps significant with regard to the impaired nutrition of the tissues of the aged that the concentration of mucopolysaccharides is not so great in many of their connective tissues as it is in those of the young.

In our example of an uncalcified tissue, *dermis* (Fig. 1), all three mechanisms for nourishing cells beyond the capillaries can conceivably operate: (1) circulation of tissue fluid, (2) diffusion through tissue fluid, and (3) diffusion through the intercellular substances. It is difficult, until more information is available, to estimate the percentage of the total function which is carried out by each of these three possible mechanisms. For our purpose, however, it is enough to appreciate that three mechanisms provide dermis with a considerable reserve, so far as the nutrition of the cells of the dermis and epidermis are concerned.

The Mechanism in Cartilage

Hyaline cartilage, like other connective tissues, consists of cells and non-living organic intercellular substance (Fig. 2). The cells live in *lacunae* in the intercellular substance which consists of collagenic fibers embedded in the mucopolysaccharide cement substance, chondroitin sulphuric acid. The mucopolysaccharide and the collagenic fibers of the intercellular substance have approximately the same refractive index; hence in fresh, and even in most stained, preparations the intercellular substance of hyaline cartilage appears homogeneous.

No capillaries are present in typical hyaline cartilage; it, like the epidermis of skin, is a non-vascular tissue and its cells, like those of the epidermis, must be nourished by one of the mechanisms that operate beyond the capillaries. The one that operates in cartilage is the third we described, diffusion through a gel.

The intercellular substance of hyaline cartilage, like a stiff jelly, contains a large percentage of water. The water, however, which is the dispersion medium of the gel, is

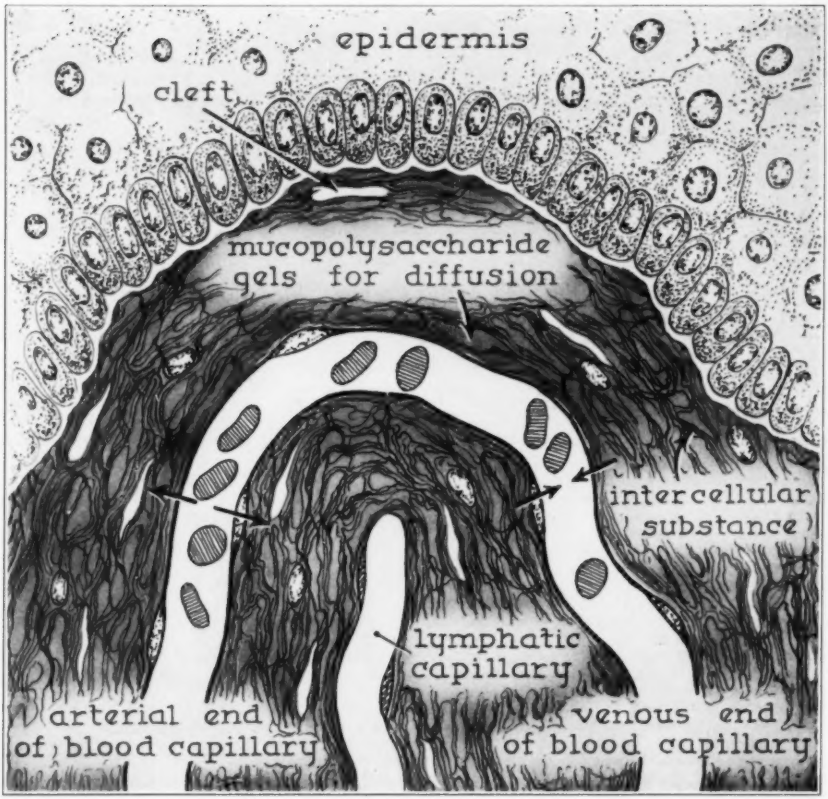

FIG. 1

Diagram of a capillary loop in the dermis, just below the epidermis. The capillary lies in connective tissue; the fibers of this are represented by lines and the mucopolysaccharide in which the fibers lie is shown in gray. Arrows through the capillary wall indicate sites of the formation and absorption of tissue fluid. Clefts are shown in the mucopolysaccharide gel; these, some think, may exist to permit circulation of tissue fluid under normal conditions. The gel is represented as serving as a means of diffusion between capillaries and the cells of the dermis and epidermis.

just as much a part of the gel as its dispersed phase; both are needed to give the intercellular substance of cartilage its special consistency and other distinctive properties. The fluid which is present in cartilage, being an integral part of its gel structure, must be thought of as being of a somewhat different order from free tissue fluid and indeed it leaves no room in the substance of the intercellular material for free tissue fluid. Hence, although the exterior of a given formed cartilaginous structure can be bathed in free tissue fluid, the individual cells of cartilage cannot be; they must be nourished by diffusion through the gelled intercellular substance within which they lie (Fig. 2). That the cells of cartilage are nourished by diffusion through the gelled intercellular substance in which they lie has serious repercussions with regard to their welfare when cartilage becomes calcified.

The calcification of cartilage and its effects: Not all aspects of the calcification process in cartilage are thoroughly understood. It is generally believed, however, that, as cartilage cells mature and become very large, they secrete alkaline phosphatase which acts to increase the concentration of phosphate ions about them. Since it is probable that the fluid of the gelled intercellular substance is already almost saturated with calcium salts, the

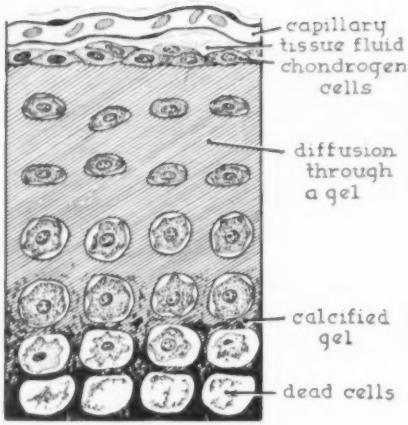

FIG. 2

Fig. 2: Diagram of a section of hyaline cartilage. A capillary which forms tissue fluid is shown outside the limits of the cartilage. For the cells of the cartilage to be nourished, substances, dissolved in tissue fluid, must diffuse through the gelled intercellular substances of the cartilage to deeply buried cells. If the intercellular substance becomes calcified, as is indicated in the lower part of the diagram (black), diffusion cannot occur and the cells die.

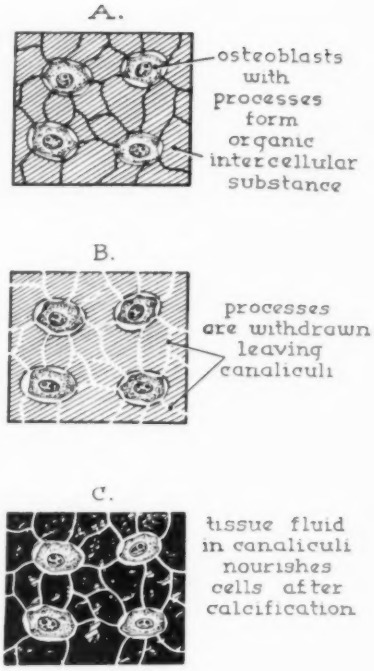

FIG. 3

Fig. 3, *A:* Diagram showing that osteoblasts have connecting cytoplasmic processes, so that the organic intercellular substance they form necessarily surrounds their connection processes.

B: Diagram showing that, when the cytoplasmic processes are withdrawn toward the cell bodies of the cells, little passageways (canaliculi) for tissue fluid are left in the intercellular substance.

C: Diagram showing how the cells of bone can be nourished through the tissue-fluid-filled canaliculi, even though the organic intercellular substance becomes calcified (black).

addition of more phosphate ions causes precipitation of certain of the more insoluble calcium salts. It seems certain, moreover, that the intercellular substance has either a physical or a chemical affinity for the precipitate; so, as it forms, it settles into the gel structure. This almost completely destroys the gel's ability to serve as a means for diffusion. As a consequence, when the intercellular substance of cartilage becomes calcified, the cells contained in the intercellular substance are deprived of their means of nutrition and of ridding themselves of waste products; so they die (Fig. 2, lower stratum).

The Mechanism in Bone

The calcification of the organic intercellular substance of a connective tissue can be looked upon as an attempt by nature to provide a strong rigid weight-bearing tissue. In the instance of cartilage, nature's experiment was not very successful for, although the calcification of the intercellular substance does temporarily increase the ability of cartilage to bear weight, it kills the cells of cartilage; and, after this has happened, the calcified intercellular substance tends to dissolve and to disappear. Why the persistence of a calcified intercellular substance should depend upon living cells being distributed throughout it is not thoroughly understood. It seems probable, however, that without the continued production of phosphatase by the cells, the mineral deposit tends to go back into solution and, when this occurs in the living body, the organic intercellular substance in which it was deposited simultaneously dissolves away. This suggests that the calcification of the organic intercellular substance represents the firm chemical union of the mineral and the organic intercellular substance, so that a new substance is formed from which the mineral

cannot later be abstracted without the organic material dissolving away as well. Sylvén has made studies on this matter.[10,11,12]

The problem of bringing about the calcification of the organic intercellular substance of a connective tissue without depriving the cells distributed throughout its intercellular substance of nourishment was solved by the evolution of bone. Bone, although very similar to hyaline cartilage, differs from it in one very important respect which will now be described.

The cells which give rise to the intercellular substance of bone, *osteoblasts*, differ from the chondroblasts which give rise to the intercellular substance of cartilage chiefly because they possess many long cytoplasmic processes which extend out from their cell bodies just as the legs of a spider extend out from its body (Fig. 3,*A*). Hence, when osteoblasts lay down the organic intercellular substance of bone, they do so not only around their cell bodies, which therefore come to occupy lacunae, but also around their processes (Fig. 3,*A*). After the intercellular substance "sets" (Fig. 3,*B*), the cell processes can be withdrawn toward the cell bodies. This procedure leaves a great number of tiny little canaliculi (Fig. 3,*B*) in the intercellular substance; these radiate out from each lacuna. Since the cellular processes of adjacent cells formerly joined one another, the canaliculi from one lacuna communicate with those of others and, as we shall see, they extend to surfaces where tissue fluid is present and where it gains entrance to the canaliculi to fill them, and all the space in the lacunae not taken up with the cell bodies of the bone cells, with tissue fluid. Because of the canaliculi and their content of tissue fluid, the calcification of the organic intercellular substance does not shut the cells of bone off from their nutrition (Fig. 3,*C*).

Since the canaliculi are of a very fine caliber, it is difficult to believe that there is any substantial degree of circulation of tissue fluid in them. More probably nutriment reaches bone cells by means of diffusion along the canaliculi filled with tissue fluid. Bone, then, offers an example of the second basic mechanism for nutrition beyond the capillaries which we discussed, diffusion through tissue fluid. But the amount of tissue fluid available for diffusion is so limited, because of the very fine caliber of canaliculi, that the mechanism in bone is not very efficient, and hence it cannot operate over any but very short distances. Actually, both in compact and cancellous bone, the great majority of bone cells are not more than one-tenth of a millimeter away from a capillary and only an occasional one exists one-quarter of a millimeter away from a capillary. This fact is reflected in the microscopic structure of both cancellous and compact bone as follows:

Relation of Blood Supply to the Fine Structure of Bone

1. *Cancellous bone:* The trabeculae of cancellous bone are bathed in tissue fluid which is derived from the capillaries of the marrow spaces between the trabeculae. Within each trabecula, canaliculi extend out from each lacuna and anastomose with canaliculi from all adjacent lacunae (Fig. 5). Canaliculi from the more superficial lacunae, moreover, extend to the exterior of the trabecula and so permit tissue fluid to enter the anastomosing canalicular system of the trabecula. Consequently, food substances, to reach the bone cells in the middle of a trabecula that is one-fifth of a millimeter in thickness, must diffuse along the canalicular system for one-tenth of a millimeter. From measurements taken on cancellous bone obtained from several different areas, it would appear that, if trabeculae are more than one-fifth of a millimeter in thickness, they generally have blood vessels disposed in canals near their middles to provide the more deeply disposed bone cells with nourishment.

2. *Compact bone:* The bone cells of compact bone are no farther away from capillaries than are those of cancellous bone. Compact bone is made up of Haversian systems; each of these consists of several concentric layers of bone, each with its quota of bone cells, arranged around a central canal which contains a capillary. The size of a Haversian system,

like the thickness of a trabecula of cancellous bone, is limited by the necessity of having all of the bone cells which it contains no farther than about one-tenth of a millimeter from a capillary. Hence, Haversian systems (as measured in the radius of a dog) are generally no more than one-fifth of a millimeter in diameter; so that the canalicular mechanism that extends out from their central canals does not have to operate over a distance greater than about one-tenth of a millimeter to supply the bone cells in the outermost layers of the system.

Since Haversian systems tend to run longitudinally, the blood vessels in their central canals also run longitudinally; and, since the systems are of such a limited width, the longitudinally disposed blood vessels in Haversian canals are relatively close together, generally not more than one-fifth of a millimeter apart, and often closer. Consequently the capillary bed of compact bone is of an extraordinary magnitude.

From the foregoing it is apparent that, although the canalicular mechanism solved the problem of keeping the cells of a calcified connective tissue alive so that the tissue could have some permanence, it is at best an inefficient mechanism for nutrition beyond the capillaries and hence its effective operation requires that bone be constructed in such a fashion that no bone cell is ever more than a fraction of a millimeter from a capillary. This basic feature of bone, as we shall see, is one of the two important reasons that the growth, repair, and grafting of bone are relatively complicated. The other basic feature about bone, which complicates its growth, repair, and grafting still further, is the fact that its organic intercellular substance, because of the secretion of phosphatase by the osteoblasts which give rise to the organic intercellular substance, calcifies almost immediately after its formation. This feature of bone also prevents it from growing in as uncomplicated a way as uncalcified tissues.

GROWTH

The Interstitial Growth of Uncalcified Tissues

If two pins could be inserted into the skin of a growing child as in the upper part of Figure 4 and left in place, they would, as the child grew, become separated as is shown in the lower part of Figure 4. This is because uncalcified tissues increase in size by interstitial growth; the tissue literally expands from within, with cells here and there dividing and forming new intercellular substance, so that the tissue increases in bulk in much the same fashion as does bread dough when it "rises". Interstitial growth is only possible in a connective tissue if the intercellular substance is sufficiently malleable to permit its being steadily expanded from within. The dermis of skin is sufficiently plastic to permit this type of growth, and so is hyaline cartilage; indeed, if hyaline cartilage could not grow interstitially, most bones could not increase in length, as we shall see later.

The Appositional Growth of Calcified Tissues

Bone, since its organic intercellular substance becomes calcified almost as soon as it forms, is not sufficiently plastic to expand by means of interstitial growth. Indeed, bone could no more be expected to expand from within than a piece of limestone. Hence pins placed in a continuous piece of bone never become any farther apart (Fig. 5). A piece of limestone can, however, if it is placed in a calcifying stream, become larger by means of further lime being deposited on its surfaces. Similarly, bone can only increase in size by means of new bone being deposited on one or more of its surfaces by osteoblasts. This is known as *appositional growth and this is the only way that bone can grow.*

The covering and lining cells of bone: Since all growth of bone is a surface phenomenon, there must be cells present on bone surfaces which can form bone. Indeed, all outer surfaces presented by any normal bony structure are always covered, and all inner ones are lined with a continuous layer of special cells (Fig. 5,*A*). These are of two sorts: (1) the less differentiated and more elongated *osteogenic* cells which, as is readily demonstrated in the

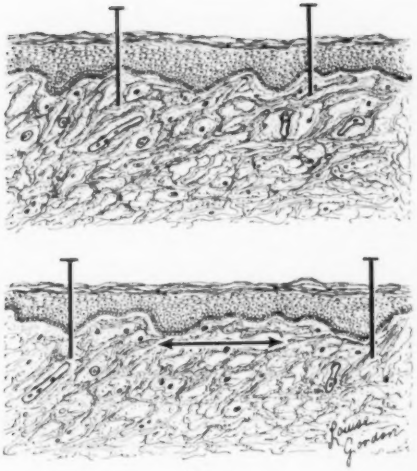

FIG. 4

Fig. 4: Diagram showing the interstitial growth of skin.

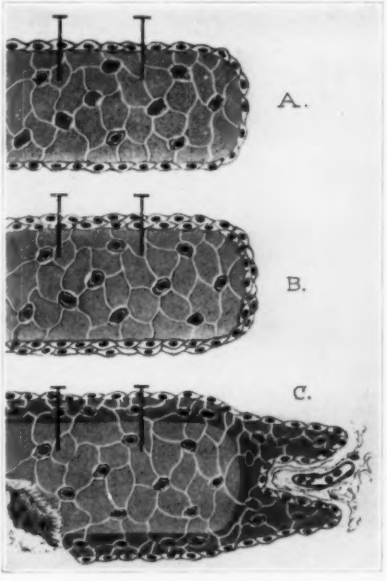

FIG. 5

Fig. 5: Diagrams showing that bone cannot grow by the interstitial mechanism, but only by appositional growth which requires new layers of bone being deposited on surfaces.

A: This shows that a trabecula of bone is covered on all surfaces with a layer of osteogenic cells (or osteoblasts).

B: This shows that the surface cells can proliferate so as to increase their numbers.

C: This shows that the innermost layer of surface cells can form a new layer of bone by secreting organic intercellular substance about them, and that the surface still remains covered by a continuous layer of osteogenic cells except at a site of resorption, where an osteoclast is present. This is shown at the lower left corner. At the right end, the diagram illustrates how new bone can be laid down on surfaces, extending the length of a trabecula to surround a capillary, so that the cells of the newly formed bone will have a source of nutrition.

repair of fractures [2], have the capacity to become either chondroblasts or osteoblasts, and (2) somewhat more differentiated and plumper osteoblasts, which are the immediate precursors of bone cells.

How layers of bone are formed on surfaces: Both osteogenic cells and osteoblasts can divide by mitosis, and so increase their numbers. Osteogenic cells, moreover, can readily differentiate into osteoblasts. Hence, by the division of osteoblasts or the division and differentiation of osteogenic cells or both, the number of surface cells can be increased, so that they form two layers instead of one (Fig. 5,*B*). Then the osteoblasts of the deeper layer can lay down intercellular substance around their cell bodies and processes to become bone cells and by this means a new layer of bone is added to the surface which is still covered with a continuous layer of osteogenic cells or osteoblasts or both (Fig. 5,*C*).

Having described the mechanism whereby bone grows by layers of new bone being deposited on a surface, we can now suggest that the mechanism cannot operate so simply as may be thought for a reason we have already discussed—the fact that no bone cell can exist if it is more than a fraction of a millimeter away from a capillary. Consequently, if many new layers of bone as such were added to any surface, say of a trabecula of cancellous bone, they would soon remove the cells of the original trabecula and even those in the deeper layers of new bone, so far away from the surface that they would be too far away from a capillary to survive. Accordingly, the growth of bone is not only a matter of layers of new bone being added to a surface, but a matter of new layers being added in such a way that no bone cell in any of the layers that are deposited is more than a fraction of a millimeter away from a capillary (Fig. 5, *C*, right). The way in which this is accomplished in the growth of a long bone will be described later.

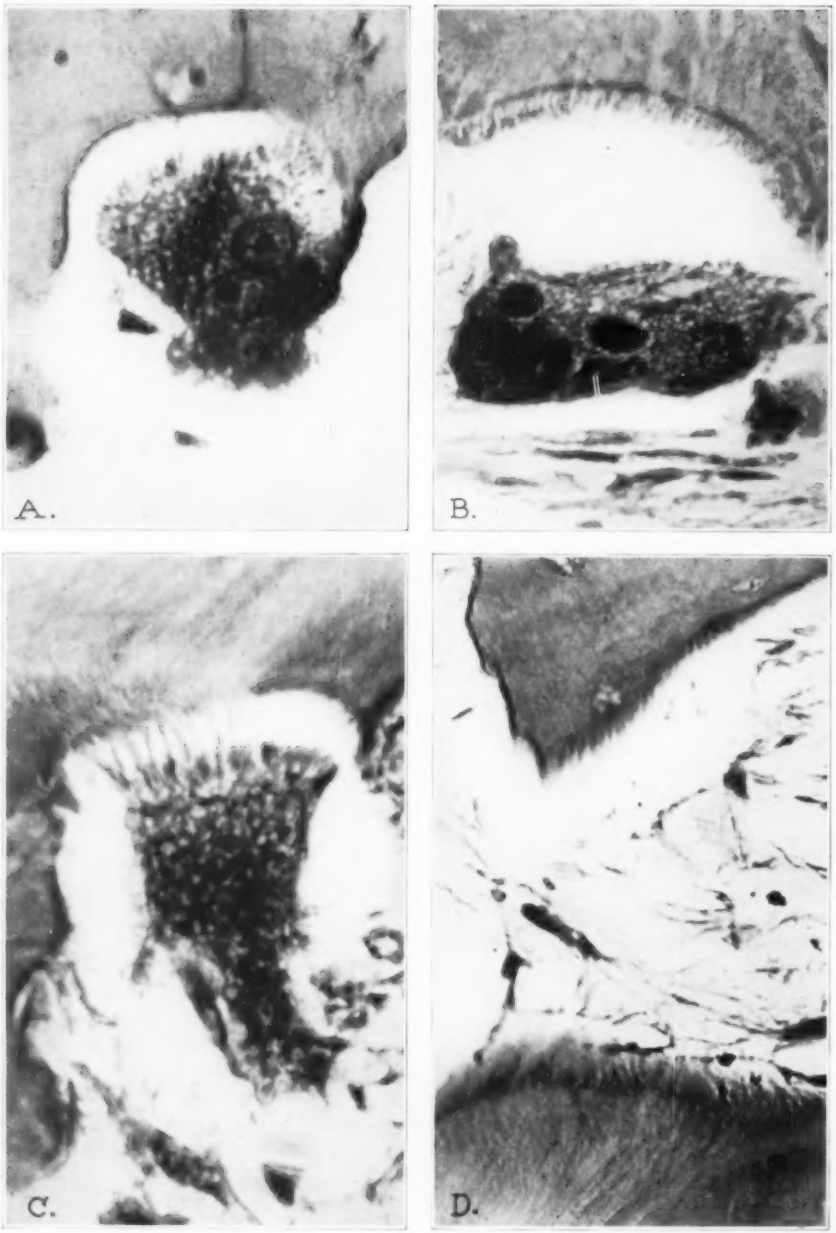

FIG. 6

A: Photomicrograph (× 1250) of an osteoclast in a Howship's lacuna. The surface of the osteoclast facing the bone exhibits a striated border.

B: Photomicrograph (× 1250) of an osteoclast which has shrunken away from the bone. The striated border is present on the bone surface instead of on the osteoclast.

(*Continued from page 708*)

Fig. 6, *C:* Oil-immersion photomicrograph, taken with the phase microscope, of an osteoclast. This shows that the striations of its striated border continue into the intercellular substance of the bone as collagenic fibers and fibrils.

D: Photomicrograph (× 1250) of striated borders of resorbing bone surfaces in sites where osteoclasts are not present.

Bone Resorption

The growth of a bone, in contrast to the growth of bone as a tissue, requires that bone resorption as well as appositional growth occur. The reason for this is that bony structures are not malleable and hence *the only way that the shape and size of any bony structure can be changed is by bone being added to, and taken away from, its various surfaces* (Fig. 5,*C*). Before discussing the growth of a bone we must therefore consider the mechanism of bone resorption.

Since the time of Kölliker it has been generally believed that bone is built by specific *osteoblasts*, and destroyed by specific *osteoclasts*. Certainly these large multinucleated cells are commonly seen along bony surfaces where resorption is occurring, often in little lacunae which they seem to have eroded (Fig. 6,*A*). But an individual who is caught at some site where a crime has previously been committed is not necessarily the criminal; the individual who is caught may have been attracted to the site by, say, the sound of a pistol shot. And so it can be argued that osteoclasts, because they are seen at sites of resorption, are not necessarily the cause of the resorption; they might just as well be the result of the resorption,—syncytial masses which form at sites where bone is melting away.

The cytoplasmic borders which osteoclasts present to bone often appear striated (Figs. 5,*C* and 6,*A*); "as though covered with fine short cilia" to use Mallory's description. Mallory, some years ago, stated that these striated borders suggest that the erosive action of the osteoclast may be mechanical in nature to some extent. Some recent preparations obtained from muscle into which both thrice-frozen-and-thawed and untreated cancellous bone chips had been transplanted for four weeks, in an experiment conducted by Stuart Gordon and the author, proved to be very favorable for the study of the striated borders of osteoclasts and informative about their nature. Sections of both thrice-frozen and untreated cancellous bone left in muscle for four weeks showed a good deal of resorption and a good many osteoclasts. Some of the osteoclasts revealed striated borders (Fig. 6,*A*). Others revealed none, but striated borders were present on the bone surface from which the osteoclasts had shrunken (Fig. 6,*B*). Still other osteoclasts were found in which the striated border was continuous between the osteoclast and the bone (Fig. 6,*C*) and in some of these it was possible, particularly with the phase microscope, to show that the cilia-like structures formerly believed to be parts of the osteoclast, were continuous with, and indeed were the free ends of, the collagenic fibers and fibrils of the organic intercellular substance of bone (Fig. 6,*C*). It is significant that these so-called striated borders of osteoclasts are in our experience only to be seen on bone surfaces where the collagenic fibers of the bone are disposed roughly at right angles to its surface.

A further search of this same material revealed striated borders on bone surfaces at which the fibers approached the surface, roughly at right angles, even if no osteoclasts were present (Fig. 6,*D*). It appears, then, that the so-called striated borders of osteoclasts are nothing more than the fringed surfaces of bone at sites where bone is dissolving away and that this appearance can be seen on bone surfaces where resorption is occurring, whether osteoclasts are present or not. These findings suggest that the mineral deposit of bone is contained chiefly in the mucopolysaccharide cement substance which lies between the collagenic fibrils and fibers of the intercellular substance and that, when bone dissolves away at surfaces, the mineral-containing cement and the collagenic fibrils do not dissolve together; instead, the mineralized cement substance always seems to dissolve away a little ahead of the collagenic fibrils which, therefore, are freed to project for a short distance, like

cilia, from the surface of the bone. They in turn, however, appear to melt away at their free ends at about the same rate as the mineralized cement dissolves, so that the fringed cilia-like edge of the bone never becomes very thick (Fig. 6,*D*).

The foregoing observations provide grounds for doubting if osteoclasts are so essential for, and potent in, bone resorption as has been generally believed. And indeed, there are other reasons for questioning if there is a need for any specific cellular mechanism to bring about the resorption of bone. It might be suggested that the problem of bone resorption is probably better regarded as the negative aspect of the positive problem which relates to maintenance of the mineral content of bone at surfaces where bone salt comes into contact with tissue fluid. The problem of preventing the salt of bone from dissolving into tissue fluid at surfaces is presumably solved by all bone surfaces, except where resorption is occurring, being covered (or lined) with a continuous layer of osteogenic cells and osteoblasts. The covering and lining cells of bone can make phosphatase and this suggests that they more or less continuously do so and so maintain an environment at the bone surface which favors deposition rather than the solution of bone salts. If bone surfaces are left naked to the tissue fluid, or if cells other than osteogenic cells and osteoblasts directly abut on a bone surface, resorption tends to occur. Since osteoclasts do not protect bone surfaces, it is only natural that resorption should occur from bone surfaces which they cover. This suggests that their role is negative rather than positive and permits us to understand why resorption also occurs from naked surfaces or when other types of cells, such as tumor cells, abut directly on bone.

THE GROWTH OF A LONG BONE

As is well known, the growth of a long bone depends upon the interstitial growth of cartilage. In bones without epiphyseal plates, with a few exceptions, it is the interstitial growth of the articular cartilages that accounts for all the bone's increase in length. In bones with epiphyseal plates, however, interstitial growth in the articular cartilages accounts only for the growth of the epiphyses (Fig. 7), and interstitial growth in the plates accounts for the remainder of the growth in length of the bone (Fig. 7). It is important to realize that the replacement of cartilage by bone either on the inner aspect of a growing articular cartilage or on the diaphyseal side of an epiphyseal plate represents the deposition of new bone on a surface—a surface that is always changing and advancing as long as the cartilage continues to calcify and disintegrate (Figs. 7 and 8). Part of the surface is calcified cartilage, but another part is the outer limit of the bone which already extends into cartilage (Figs. 7 and 8). Hence, such new bone as forms in calcified cartilage generally adds to the extent, as well as to the density, of the bone which already is present in the cartilage. Thus the replacement of cartilage is brought about by the appositional growth of bone.

The new bone which is formed on the diaphyseal side of an epiphyseal plate is deposited in thin layers along the sides of the remnants of the cartilaginous partitions which were formerly disposed between the longitudinally disposed rows of cartilage cells in the plate (Figs. 7 and 8). This new bone makes a firm union with the cartilaginous remnants which, of course, are still continuous with the cartilage of the plate; as a consequence the diaphysis is firmly cemented to the epiphyseal plate over a considerable surface. The new bone is cancellous and appears in longitudinal sections as consisting of thin trabeculae which have cartilage cores (Figs. 7 and 8). This region is known as a *metaphysis* and, except at its periphery, the bone here never becomes compact. Furthermore, the metaphysis itself does not become thicker, because the trabeculae, while they continuously extend into the cartilage of the plate, melt away at their free ends just as continuously (Fig. 7).

In the periphery of the metaphysis, the bone does not remain entirely cancellous because the osteoblasts here tend to lay down more than one layer of new bone on the cartilaginous remnants that persist (Fig. 7). This makes the trabeculae at the periphery

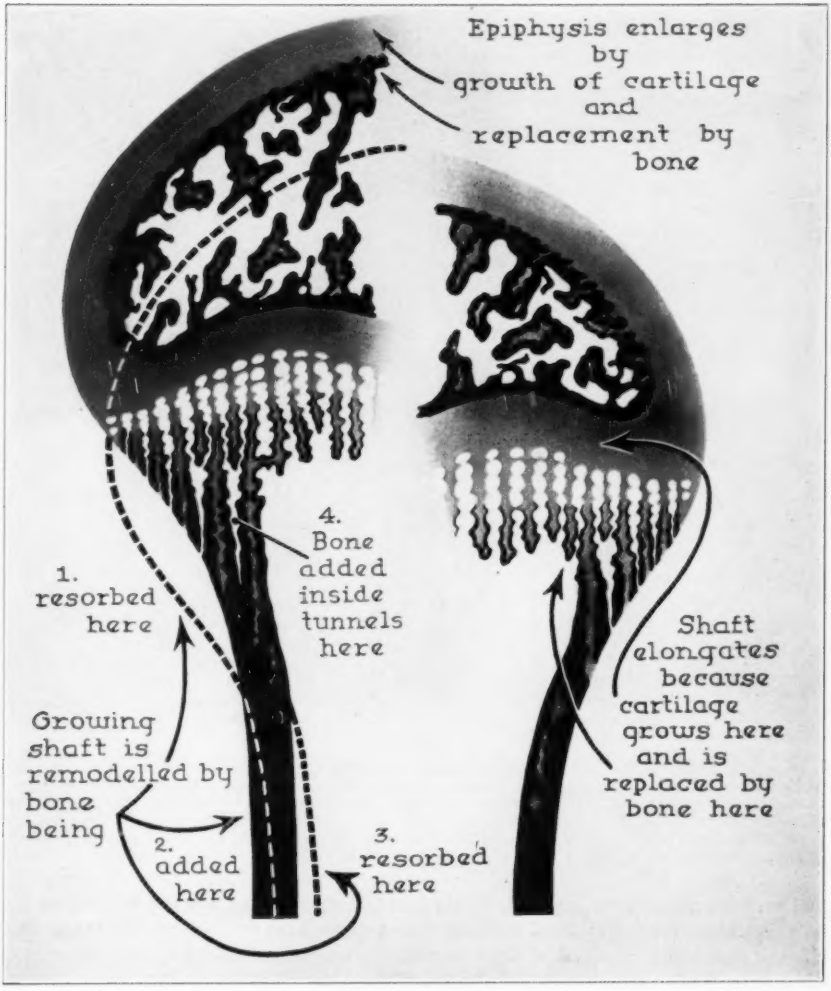
Epiphysis enlarges by growth of cartilage and replacement by bone
4. Bone added inside tunnels here
1. resorbed here
Growing shaft is remodelled by bone being
2. added here
3. resorbed here
Shaft elongates because cartilage grows here and is replaced by bone here

FIG. 7

Diagram showing surfaces on which bone is deposited and resorbed to account for the remodeling that takes place at the ends of growing long bones that have flared extremities.

of the metaphysis thicker than they are in the more central part of the metaphysis and it likewise makes the spaces between the peripheral trabeculae narrower (Fig. 7).

It is easy to get the impression from longitudinal sections of growing bone that the trabeculae of the metaphysis are like stalactites, hanging down from the diaphyseal side of the plate. If, however, cross sections are cut of the metaphyses of larger mammals, close to the plate, it will be found that only the free ends of these are stalactite-like, and that closer to the plate the structures which in longitudinal sections appear as stalactite-like trabeculae are not individual entities but parts of a continuous honey-comb structure [2]. Therefore, close to the plate, the intertrabecular spaces seen in longitudinal sections are the lumina of cartilaginous tunnels which are lined first with a layer of bone and inside

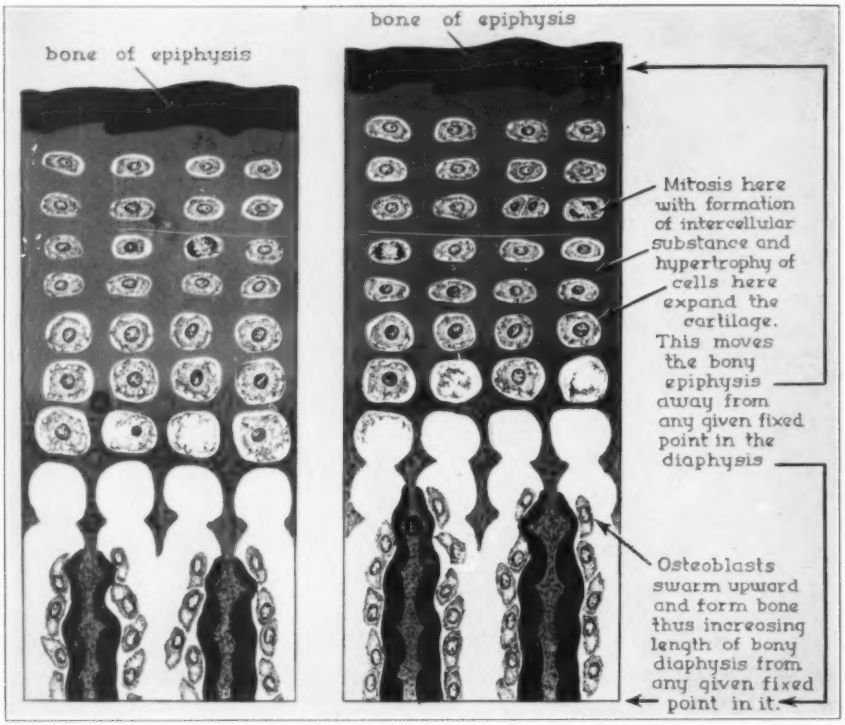
bone of epiphysis
bone of epiphysis
Mitosis here with formation of intercellular substance and hypertrophy of cells here expand the cartilage. This moves the bony epiphysis away from any given fixed point in the diaphysis
Osteoblasts swarm upward and form bone thus increasing length of bony diaphysis from any given fixed point in it.

FIG. 8

Diagrams of two longitudinal sections cut through the same epiphyseal plate and part of the diaphysis of growing long bone. The diagram on the right illustrates the changes that occur in what is represented in the left, over a short space of time. Cartilage is gray, calcified cartilage is stippled, and bone is black. The sites labelled *A* and *B* are fixed points and remain at the same level in both diagrams. Note, however, that "bone of epiphysis" has moved upward in the diagram on the right, and that the level of calcified cartilage and bone is also higher in the diagram on the right.

this, with osteogenic cells and osteoblasts (the latter, of course, are the cells which cover the trabeculae of a longitudinal section). The tunnels each contain central blood vessels which appear in longitudinal sections as capillary loops that extend toward the cartilage between the trabeculae.

The Remodeling That Occurs During the Growth of a Long Bone

The diaphyses of many long bones flare outwardly as they approach their epiphyses, so that the bones are of a much greater diameter in their metaphyseal region than in their mid-sections (Fig. 7). The changes which occur in the expanded ends of diaphyses as a bone grows in length will now be described. (Lacroix has paid a great deal of attention to this matter and Leblond, Wilkinson, Bélanger, and Robichon have recently made splendid radio-autographic studies of this area in growing bones.)

First, as the study of Figure 7 will show, the site along the longitudinal axis of the bone occupied by a flared extremity will, as the bone continues to elongate, come later to be occupied by a tubular and considerably narrower portion of the shaft. This means that what is the flared portion of a shaft at one time must become a narrower tubular portion of the shaft at a later time. This requires that bone be resorbed from the exterior of the flared portion and built up on its interior (Fig. 7). Since cartilaginous remnants can be seen in at

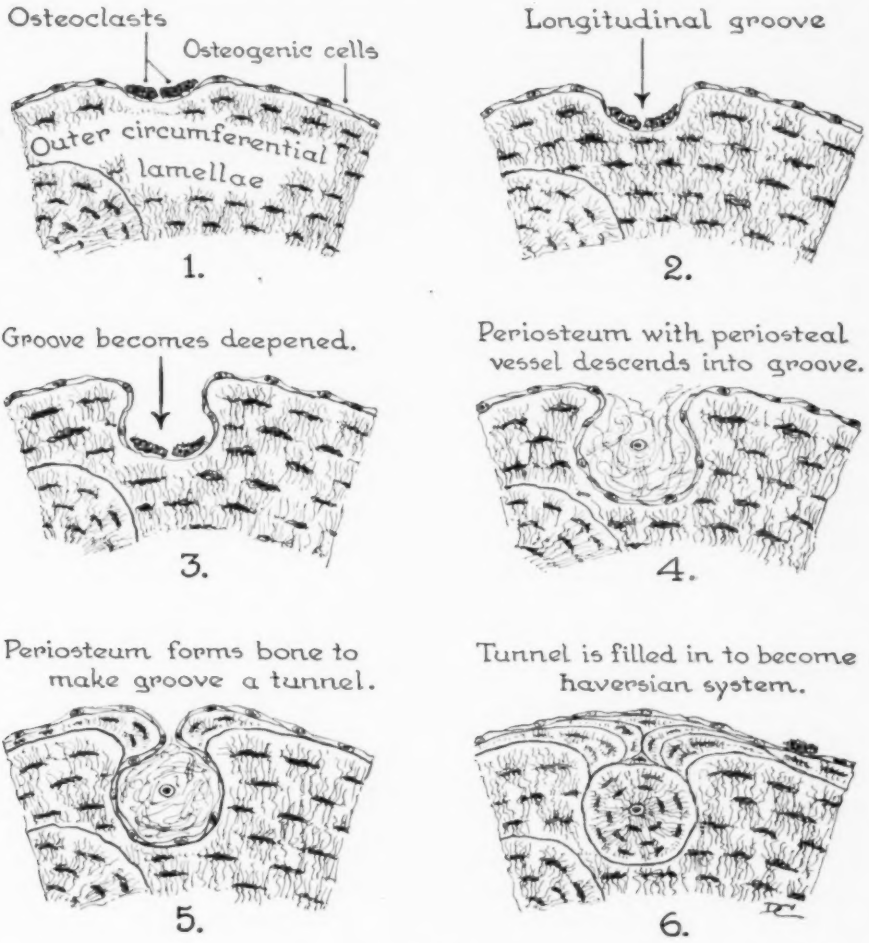

FIG. 9

Diagrams of cross sections of the shaft of a bone showing how new Haversian systems are laid down under the periosteum to replace outer circumferential lamellae. (Reproduced by courtesy of J. B. Lippincott Company from *Histology* by A. W. Ham, Fig. 136, Philadelphia, 1950.)

least the outer layers of the tubular bone which forms as a consequence of the flared portion being remodeled (Fig. 7), it is apparent that a good deal of the new bone which forms on the inner aspect of the cortex of the flared extremity in the remodeling process (Fig. 7) is derived from the filling in of cartilage tunnels which were once in the periphery of the epiphyseal plate, on its diaphyseal aspect.

Secondly, because of their manner of origin, these filled-in tunnels, which are at least the counterparts of Haversian systems, are parallel to the rows of cells in the epiphyseal plate and hence to the long axis of the bone as a whole, and since the line of the exterior of the metaphysis is not parallel either to them or to the bones as a whole, but flares out-

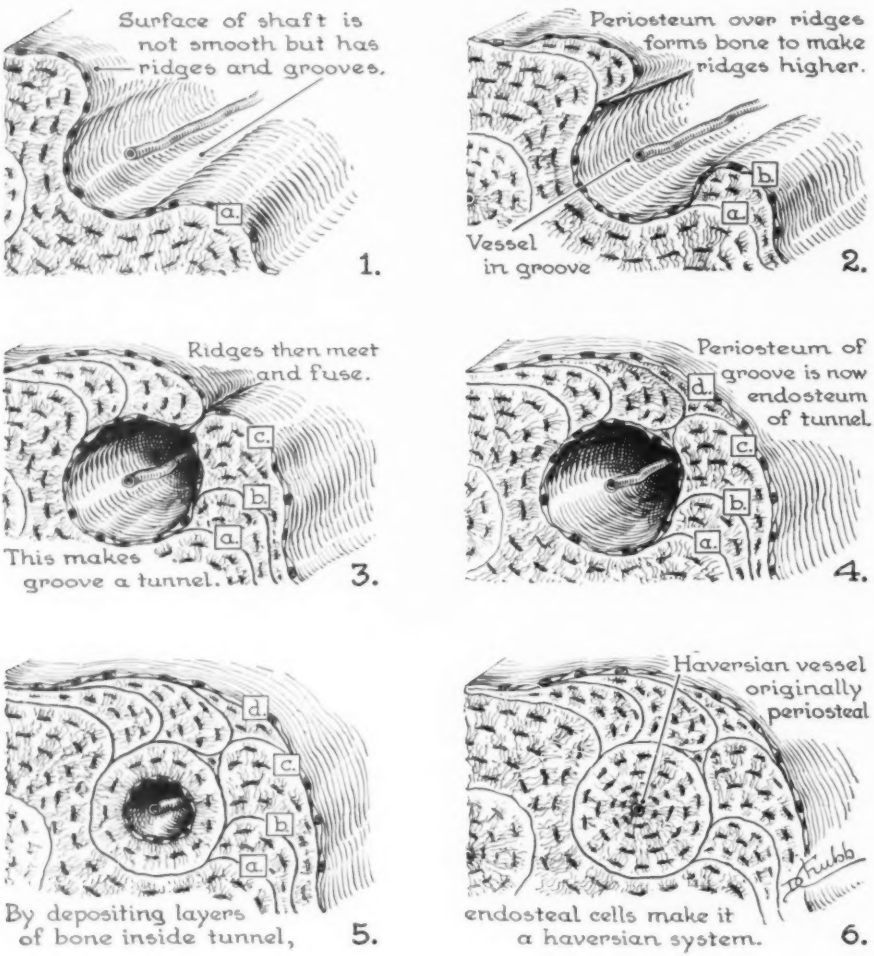

FIG. 10

Three-dimensional diagrams to show how the longitudinally disposed grooves on the exterior of a growing shaft become roofed over to form tunnels and how these become filled in to form Haversian systems which thereupon are added to the exterior of the shaft. These diagrams also show how the blood supply of the shaft of a long bone comes to be derived, when it is fully grown, almost entirely from the periosteum by means of vessels having been buried in its substance. (Reproduced by courtesy of J. B. Lippincott Company from *Histology*, by A. W. Ham, Fig. 135, Philadelphia 1950.)

wardly in this region, the canals of these systems pass through the forming cortex of the metaphysis obliquely (Fig. 7). Because these canals are straight, fairly wide, and relatively short, there is a much freer communication between the medullary cavity and the periosteum in this region than there is in any other part of the shaft. This is probably of significance with regard to the way that untreated juvenile osteomyelitis may spread from the metaphyseal region outwardly to the subperiosteal zone.

Thirdly, the tubular shaft increases in diameter during the growth period and at the same time resorption occurs on its inner surface (Fig. 7), so that its wall does not become unduly thick. The way in which shafts increase in width will now be described.

Growth in Width of Tubular Shafts of Long Bones

Since the exterior of the shaft of a long bone is intimately covered with the osteogenic layer of the periosteum, there is no problem about layers of new bone being deposited under the periosteum to make the diameter of the shaft greater. But the simple and continued deposition of layer after layer of new bone would soon remove the cells of the deeper layers so far from the capillaries of the periosteum that they would die. There must be, therefore, some provision for adding bone in the form of Haversian systems—nature's solution to the problem of nourishing cells in compact bone—to the outside of the shaft of a bone. Since Haversian systems must be built by the filling in of tunnels, this requires that there first be longitudinal tunnels in the outermost parts of the cortex which subsequently can be filled in. There are two ways by which such tunnels originate:

First, and this method is common in the later stages of growth in width, smooth layers of new bone (outer circumferential lamellae) are consecutively added to the circumference of a shaft. When the cells of the deepest layers become so far removed from capillaries that their lives are threatened, grooves of resorption appear on the surface (Fig. 9). These become deeper and sink through the new layers of bone to reach the deeper layers where nutrition is poor (Fig. 9). Osteogenic cells and blood vessels of the periosteum invade the grooves, and the osteogenic cells eventually roof the grooves over to convert them into tunnels (Fig. 9). These then become Haversian systems (Fig. 9).

Secondly, in the growing bones of the very young, no continuous smooth circumferential lamellae are laid down under the periosteum to begin with, but instead, subperiosteal growth results in longitudinally disposed ridges and grooves (Fig. 10). The osteogenic cells covering the ridges bridge them over to make them into tunnels (Fig. 10), and these then become Haversian systems.

As shafts grow in width by having Haversian systems added to their periphery by either of these methods, the older systems become buried more and more deeply as the newer ones form at the surface. And since resorption continues on the inner aspect of the shaft, so that the marrow cavity becomes increasingly wider, the first subperiosteally formed Haversian systems come to be closer and closer to the medullary cavity with their blood vessels, which were originally derived from the periosteum, eventually anastomosing with some of those of the marrow.

It is apparent from the foregoing that, as growth continues, the blood vessels of the shaft of a bone come to be composed almost, if not entirely, of vessels which were once periosteal vessels.

REPAIR

A knife that cuts skin, or a saw that cuts bone, destroys, by direct and violent trauma, the tissue with which it comes into contact. But this is not all the tissue that may be destroyed by such an operation. The knife and the saw both cut through blood vessels and this raises the possibility of additional tissue being lost as a result of its being deprived of its source of nutrition.

The amount of tissue that dies in any given part of the body, as a result of a few blood vessels being severed, depends, of course, on the number of blood vessels supplying that part and also on how extensively they anastomose with one another. But the amount of tissue that dies depends also on a second factor, — the efficiency of the mechanism for nutrition beyond the capillaries which operates in that particular tissue. With regard to both these factors there is, as we shall see, a great difference between an uncalcified tissue such as skin and a calcified tissue such as bone.

Repair in Dermis

As has already been described, probably all three mechanisms designed to provide nutrition beyond the capillaries—the circulation of tissue fluid, diffusion through tissue fluid, and diffusion through gels—operate to various extents in dermis. Accordingly the cessation of blood flow in the more adjacent capillaries to any given cell in dermis does not necessarily destroy its means of nutrition; the mechanism for nutrition beyond the capillaries is so efficient that such cells can be nourished from distant capillaries which are still in operation. Accordingly very little tissue dies as a result of such interruption of blood flow as is occasioned by a simple cut in the skin and consequently, if a skin wound is kept clean, and its edges are approximated, very little new tissue is required to restore the part to normal. Since almost no tissue, except that directly in the way of the knife, is lost, repair can begin from cells almost directly adjacent to the line of injury. Hence, on both sides of the cut the fibroblasts of the dermis proliferate and produce new intercellular substance. By this means the continuity of dermis is soon restored. Likewise the cells of the epidermis close to the cut divide, and the proliferating cells soon glide over the line of the cut to restore the epithelial surface.

Repair in Bone

As has already been described in this section, the amount of tissue lost when a few blood vessels are cut or torn in any tissue depends upon the number of vessels in the

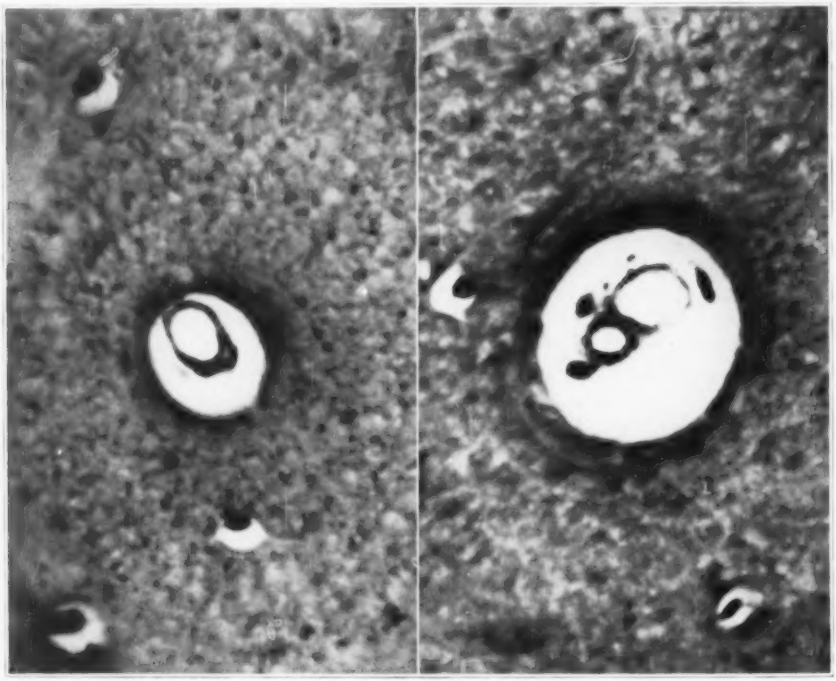

FIG. 11-A FIG. 11-B

Photomicrographs (× 800) of blood vessels in Haversian canals as they appear in cross sections of the radius of a dog. The canal in the center of Fig. 11-A contains a single vessel which is a large capillary. The canal in the center of Fig. 11-B contains two vessels, a very small arteriole, and a very small venule. The stippled appearance of the bone intercellular substance is due to the presence of canaliculi that are cut in cross section and obliquely. A few bone cells in lacunae may be seen.

tissue and the extent to which they anastomose, as well as upon the efficiency of the mechanism for nutrition beyond the capillaries which operates in that particular tissue. We shall see that, although compact bone is well supplied with capillaries, the anastomoses between these are such, and the mechanism for nutrition beyond them is such, that the interference with the blood vessels of compact bone caused by a clean break through it results in the death of a considerable amount of tissue.

The vessels in Haversian canals, like the systems themselves, run more or less longitudinally in the shaft of a bone. Hence, when a clean break occurs across a shaft, all the Haversian vessels of the part are interrupted. Most of these vessels are of the order of large capillaries (Fig. 11-A). The majority of canals in the compact bone of adults contain only one vessel, but some of the canals have two or more vessels which may then be arterioles and venules (Fig. 11-B).

After Haversian vessels are ruptured at the site of a break, they bleed and then become sealed off. Circulation in them ceases thereafter between the break and at least the nearest functioning vessels with which they anastomose; in the instance of canals with but a single vessel, this would, of course, have to be a vessel in another system or the periosteum.

In order to describe the anastomoses that exist between the vessels of Haversian systems it is necessary again to mention that practically all of the Haversian vessels of a shaft of compact bone were once periosteal vessels and that, as the bone grew in width, they became buried more and more deeply in its cortex. As they become buried, they remain connected to more superficial periosteal vessels by twigs that run in Volkmann's canals; these pass from Haversian canals to the surface at right angles or obliquely. As Haversian systems become more and more deeply buried, the original periosteal vessels to which they are connected may, in turn, become buried in the bone to become the vessels of more superficial Haversian systems. When this occurs, the Volkmann's canals which once connected superficial systems to the periosteum now merely connect the vessels of deeper systems to those of more superficial systems. The vessels in the deepest Haversian canals also become connected through Volkmann's canals to vessels in the medullary cavity of the bone. Accordingly the vessels in Volkmann's canals provide the means by which Haversian vessels can anastomose with each other and with the vessels in the periosteum and in the medullary cavity. All other factors being equal, whether much or little bone dies adjacent to a fracture line depends upon whether Volkmann's canals containing anastomotic vessels are sparse or numerous. Unfortunately there is little direct information about how numerous they are. However, since bone commonly dies for a few to several millimeters or more away from a fracture line (Figs. 12-A and 12-B), it could be estimated that there are not enough of them to provide a very rich supply of anastomoses between the vessels of adjacent Haversian systems.

Next, as has already been explained, the canalicular mechanism for nutrition beyond the capillaries in bone is very inefficient. No bone cell can be nourished through canaliculi if it is more than a fraction of a millimeter away from a functioning capillary. Hence, when the circulation is interrupted in the Haversian canals near the site of a break, the bone cells in the parts of these Haversian systems, where the vessel has ceased to function, all die. Unlike the cells in dermis, the bone cells in this area cannot be nourished by more distant and still functioning capillaries.

For all the reasons described above — the facts that (1) Haversian vessels are generally single; (2) adjacent Haversian vessels communicate with each other only infrequently; and (3) the mechanism for nutrition beyond the capillaries in bone is so very inefficient — a considerable amount of bone always dies on either side of a clean break in the shaft of a bone, because its cells are deprived of their nutrition. Consequently the healing of a fractured bone is more complicated than the healing of a cut through the skin, wherein almost no tissue to either side of the cut dies.

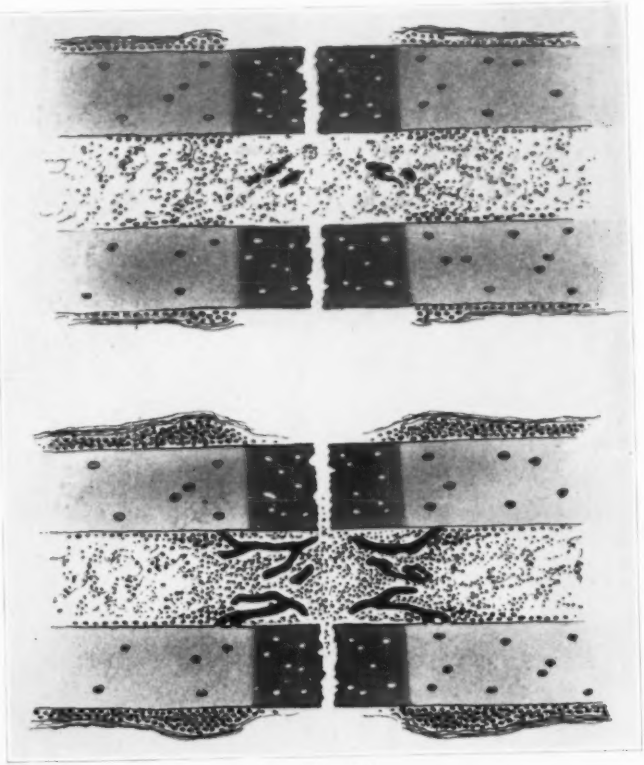

FIG. 12-A

Diagrams of longitudinal sections cut through healing fractures to show various steps in the process. Pre-existing bone, which is still alive, is light gray; dead bone is dark gray; and new bone, formed since the fracture, is black.

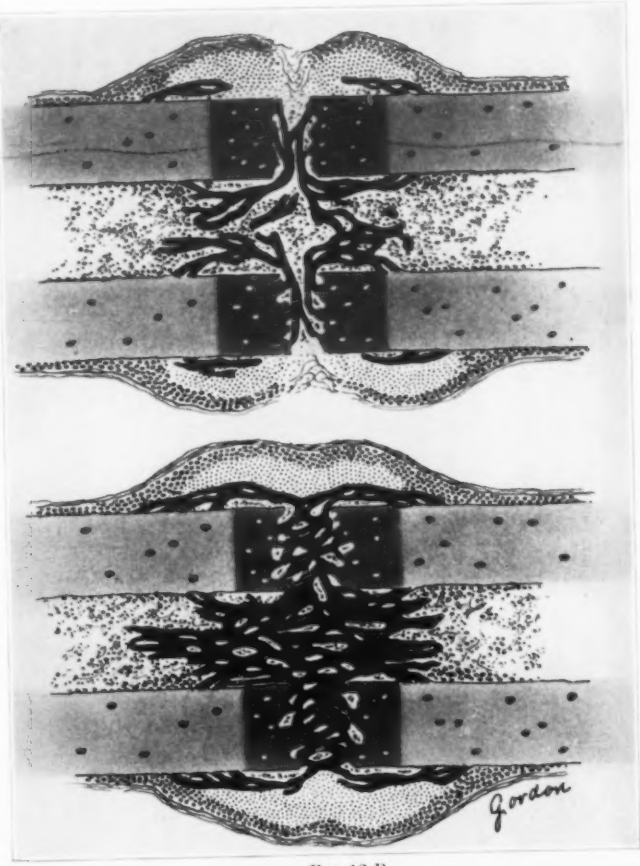

FIG. 12-B

The healing of a fractured bone, moreover, is complicated further for another reason. It will be recalled that, in the healing of skin, the fibroblasts along the edge of the cut can proliferate and grow the very short distance across the line of injury to quickly restore the continuity of the dermis. The cells of bone near the edge of the fracture line are, of course, all dead, and hence cannot perform a similar function. Even if they were not dead, they could not participate in the repair process for another reason — the fact that they are entombed in lacunae from which they cannot escape. It is obvious, therefore, that there are two problems associated with the healing of bone which are not encountered in the healing of dermis; first, there is a considerable amount of dead tissue on each side of the line of injury; and, second, the cells in bone, unlike the connective-tissue cells in dermis, cannot participate in the repair process. Such new tissue as is formed to repair bone must, therefore, come from some other source than the cells that live in bone.

The cells that usually repair bone, in my opinion, are the osteogenic cells and osteoblasts that normally cover and line bone surfaces. These cells belong to the bone and cartilage family of cells[3]. They comprise the deep layer of the *periosteum* and the *endosteum* that lines Haversian canals and the marrow cavity and covers such trabeculae of cancellous bone as lie in the marrow cavity. In addition to the covering and lining cells of bone, the undifferentiated (primitive) reticular cells of marrow can also become osteogenic and contribute toward bone repair.

The cells of the deep layer of the periosteum and the cells of the endosteum, like the cells of bone, also die for some distance from the line of fracture (Fig. 12-A, upper half). However, at the juncture of the dead and living bone — a few millimeters or more away from the site of the fracture — they soon proliferate so that they form two more or less complete rings, one of which surrounds the shaft at this site while the other lines it. At the same time some of the undifferentiated cells of the marrow, a little distance away from the line of fracture, become osteogenic, and soon little islands of new bone appear in the living marrow which abuts on the débris that results from the death of the marrow at and near the line of fracture, and the blood that pours into it. While little islands of bone are forming in the marrow, the proliferating endosteal cells extend out toward them, forming delicate new bone trabeculae, which soon connect the shaft with the trabeculae that have formed in the marrow (Fig. 12-A, lower half).

Meanwhile, proliferation continues in the deep layer of the periosteum which soon becomes sufficiently thickened to form a substantial ring around each fragment near the line of fracture. These rings of osteogenic cells continue to enlarge and, as a result, their adjacent borders gradually approach one another (Fig. 12-B, upper half) and fuse. While growth is occurring in most of the substance of the periosteal rings, differentiation begins in the parts that are farthest from the line of fracture and closest to the bone and where there are periosteal capillaries and, as a result, subperiosteal trabeculae of bone are formed at this site (Fig. 12-B, lower half). Closer to the line of fracture, and farther away from the shaft of the bone, where there are no capillaries, the cells in the osteogenic rings differentiate into cartilage (Fig. 12-B). The cartilage cells that are formed continue to proliferate and this helps to expand the rings further. Eventually the cartilage matures, becomes calcified, and is replaced by new bone, which grows into it from the site along the shafts where the first trabeculae of bone appeared.

The trabeculae which extend toward the fracture line from each fragment not only meet and fuse with each other, but also become firmly cemented to the dead bone at the end of each fragment. They do not, however, cover the dead bone completely and between the areas at which they are joined to the dead bone, resorption occurs. When the areas of resorption extend deeply into the dead bone, it comes to resemble cancellous rather than compact bone. At this time there is, therefore, a cancellous network consisting of both living and dead bone joining the two fragments. Gradually, as new bone is deposited here and there, and as the dead bone is resorbed here and there, the cancellous network

FIG. 13-A

Photomicrograph (× 20) of a cleared thick section cut through the site of an autogenous full-thickness skin graft in a pig which had been in position for five days before the blood vessels were injected. Note that the lower part of one large vessel in the graft (slightly to left of middle) is open to the circulation, being connected to the graft bed by small vessels below it.

comes to be composed almost entirely of living bone. The next tendency which operates in the remodeling of the callus is that the spaces in that part of this cancellous network which is in line with the cortex of the two fragments become filled in with successive layers of new bone so that the cancellous network becomes compact bone and, as this occurs, the more peripheral and internal trabeculae of the callus are gradually resorbed.

To sum up: The healing of a fracture is much more complicated than the healing of a skin cut, because the interruption of blood vessels that occurs when a bone is broken leads to the death of a considerable amount of the bone as well as of the covering and lining cells of bone on both sides of the fracture. Accordingly for repair to be effected even provisionally, the covering and lining cells must grow for a considerable distance from where they are still alive to reach the break and their fellows from the other fragment. This may be hazardous, because those from each side of the break may, for one reason or another, fail to keep their rendezvous with those from the other.

Furthermore, for *proper* repair to be effected, the dead bone of the shaft, on both sides of the fracture line, must be resorbed and replaced with new bone and, since both these procedures are relatively slowly performed surface operations, a considerable time must elapse before this work can be completed, and continuity by means of compact bone can be re-established.

FIG. 13-B

Frontal preparation (× 20) of autogenous free full-thickness graft in position for seven days. Note that many large vessels of the graft are open to the circulation. The upper limit of the graft bed is in approximately the middle of the picture. (Reproduced by courtesy of J. B. Lippincott Company from *Histology*, by A. W. Ham, Fig. 246. Philadelphia, 1950.)

THE BEHAVIOR OF TRANSPLANTED TISSUES

Transplants of Skin

It is generally agreed that most of the substance of a free autogenous split-thickness or full-thickness skin graft can survive transplantation and eventually becomes vascularized to form a constituent part of the tissue to which it is transplanted.

It is obvious that for the cells of a free full-thickness skin graft to survive until the graft becomes vascularized requires that there be a very efficient mechanism for nutrition beyond the capillaries operating in the graft, otherwise not enough nourishment could be transmitted all the way through the graft from the capillaries of the graft bed to keep the cells of the graft alive until it becomes vascularized. As has already been noted, probably all three mechanisms for providing nourishment beyond the capillaries operate in dermis. It is unlikely, however, that there would be any substantial degree of circulation of tissue fluid in a full-thickness graft for the first few days that it is in place; nevertheless, it appears that diffusion through the tissue fluid and gelled intercellular substances of the graft are sufficient to provide its cells with nourishment from the capillaries of the graft bed.

For the first few days that it is in place a skin graft is nourished entirely by mechanisms beyond the capillaries, for there are no functioning capillaries in the graft. But after a few days the graft becomes vascularized, and thereafter the mechanism for nutrition beyond the capillaries does not have to operate over such great distances. The way in which skin grafts become vascularized will now be discussed briefly.

A few years ago Dr. George Cloutier and the author performed some skin-grafting experiments on pigs, whose skins, unlike those of most laboratory animals, have a blood

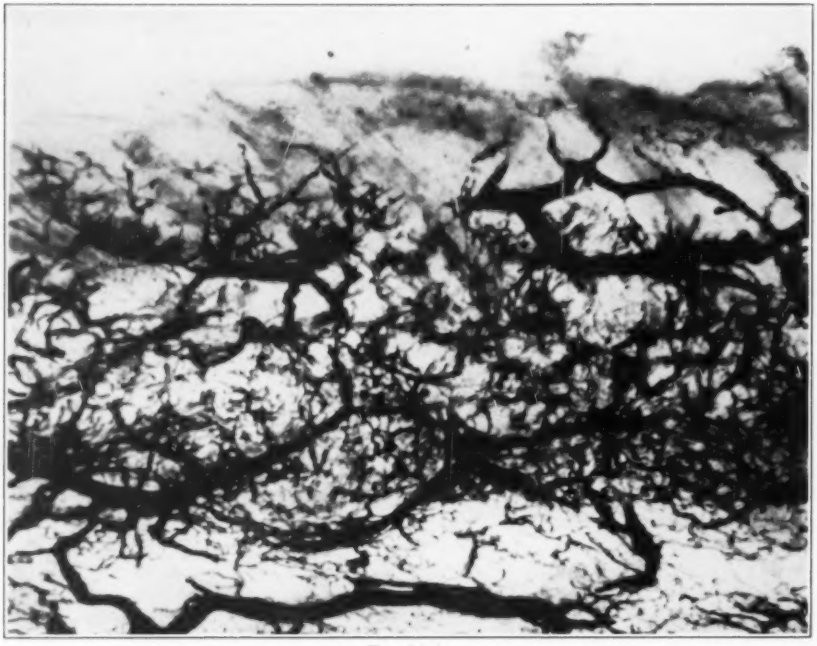

FIG. 14-A

Similar preparation (× 20) of autogenous free full-thickness skin graft in position for ten days. Note that large vessels of the graft are open to circulation and are connected, slightly below the middle of the picture, with large vessels in the graft bed by means of small vessels. (Reproduced by courtesy of J. B. Lippincott Company from *Histology*, by A. W. Ham, Fig. 246. Philadelphia, 1950.)

supply very similar to that of the skin of man. When we began these experiments, we assumed that a free full-thickness graft would become vascularized by means of new blood vessels growing up into it from the graft bed. To investigate this matter, however, we transplanted four full-thickness autografts and three full-thickness homografts to suitably prepared sites on the back of a pig on different days. By killing the pig on a suitable day, we had specimens of autografts that had been in place for three, five, seven, and ten days, and homografts for three, seven, and ten days respectively. As the pig was being killed with anaesthetic, its vascular system was perfused with a vasodilator and an anticoagulant. The aorta was then injected with a mixture of gelatin and India ink, after which the vessels were tied off and the whole region containing the grafts was fixed in formalin. Thick cleared sections were then obtained through all the various grafts (Figs. 13-A to 14-B). The injection was very successful and all the vessels open to the circulation at the time of death of the pig stood out clearly as black lines.

No injection mass was seen in the three-day autograft. In the five-day autograft, however, one large vessel extending into the graft was seen to contain some injection mass in its deeper part (Fig. 13-A). By seven days, many large vessels of the autograft were filled with injection mass (Fig. 13-B) and at ten days even more were filled (Fig. 14-B). The caliber of many of the vessels of the graft that were filled was much too great for these vessels to be new capillaries which had grown up into the graft from the graft bed and indeed, from the study of ordinary paraffin sections, stained with hematoxylin and eosin, it was clear that the large vessels in the graft which were open to the circulation at seven days were the original vessels of the graft. These had become reconnected to vessels in the graft bed, through the medium of capillaries.

FIG. 14-B

Similar preparation (× 20) of free full-thickness homograft in position ten days. Note that no vascularization of the graft has occurred, although the vascularity of the graft bed is tremendous.

The experiment by Dr. Cloutier and the author, therefore, suggests that the mechanism for nutrition beyond the capillaries in a full-thickness skin graft is sufficient to maintain the life of the cells in the walls of the original blood vessels of the graft until these vessels become connected again to the circulatory system, and that an important factor in free skin grafts becoming vascularized is the reconnection of their vessels (by means of new capillaries) to those in the bed of the graft.

It is of interest that the cells of homografts can live for several days by means of diffusion from the graft bed. Indeed, we have seen examples of mitosis in cells of homografts several days after they have been in place. However, our injection experiments showed that there was absolutely no vascularization of the homografts, either by new vessels growing up into them, or by their original vessels becoming reconnected (Fig. 14-B).

Transplants of Compact Bone

Since the canalicular mechanism for nourishing cells beyond the capillaries in bone is so inefficient, it could scarcely be expected that the bone cells in a substantial piece of compact bone, unlike the connective-tissue cells of a piece of skin, could survive transplantation until circulation was re-established. And indeed they do not and, despite early claims to the contrary, it is now generally agreed that almost all, if not all, of the bone cells of a piece of compact bone that is transplanted always die.

The same fate need not overtake all the covering and lining cells of compact bone. Under favorable circumstances there can be a survival and even a subsequent growth of the more favorably situated osteogenic cells of the deep layer of the periosteum and of the endosteum that lines the narrow cavity. There is not the same opportunity, however, for the osteogenic cells of the Haversian canals to survive, because this would require

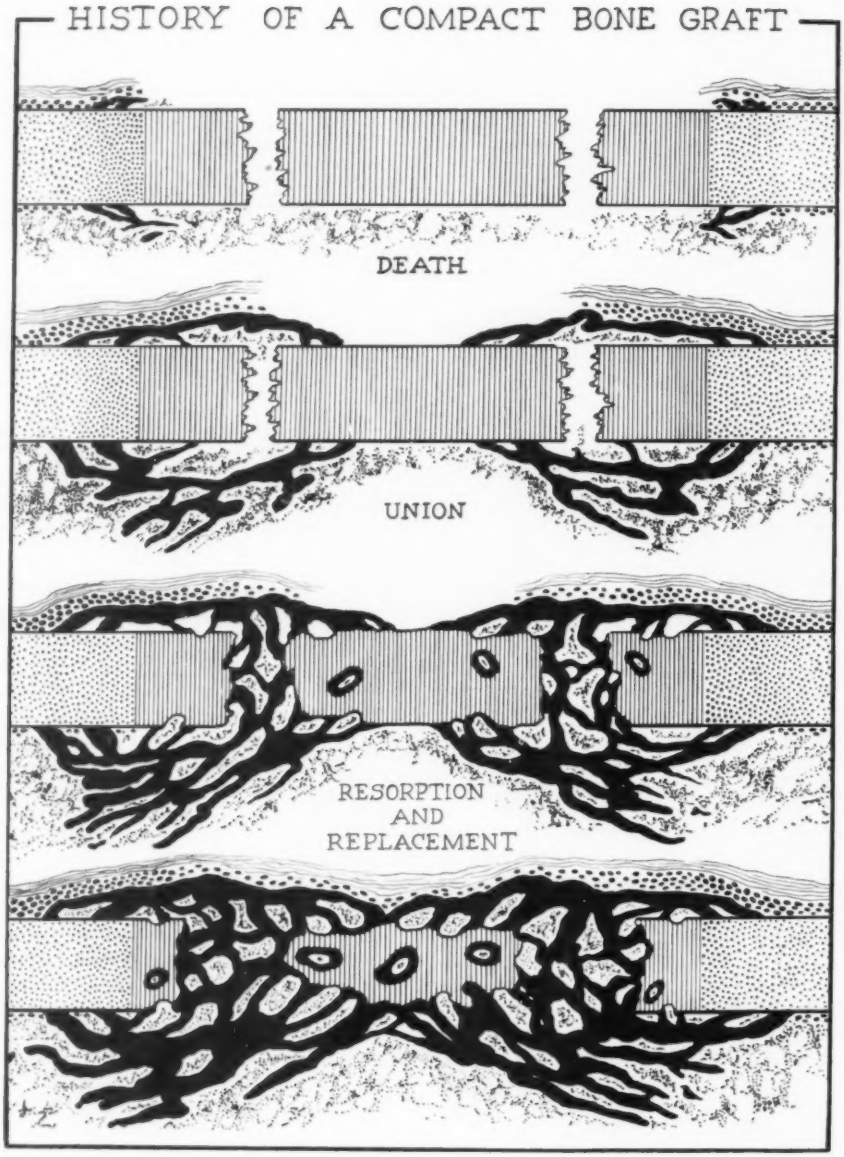

FIG. 15

Diagrams to show the steps in the history of a block of cortex of a bone which is cut free from its blood supply and placed back into the defect its removal caused. The periosteal surface is above and the marrow surface is below in each of the four pictures. Pre-existing bone still alive is shown in medium stipple, dead bone is lined, and new bone is black.

diffusion through tissue fluid over greater distances than is practical. The most that can be hoped for, then, so far as the survival of the covering and lining cells of transplanted compact bone is concerned, is that some of the more favorably situated osteogenic cells

of the periosteum and of the endosteum of the marrow cavity will survive transplantation.

It should be realized that, when a bed is cut to receive a transplant, the bone of the host dies all along the edges of the saw cut just as, and for the same reasons that, it dies close to the line of a fracture. The upper drawing in Figure 15 illustrates this point. The transplant becomes united to its bed by the same process by which a fracture heals, but with one difference: the growth of osteogenic cells responsible for the new bone that unites the transplant to its host is derived, generally for all practical purposes, from the host. The osteogenic cells and osteoblasts that grow toward the transplant come from the usual sources: (1) the deep layer of the periosteum of the host, (2) the endosteum of the host, and (3) the undifferentiated marrow cells of the host (Fig. 15). The latter source of cells can be very important.

From all these three sources osteogenic cells and osteoblasts proliferate and push out toward the transplant, forming new trabeculae of bone, and, in some instances, cartilage. After a time the bony trabeculae, increasing in length and breadth by new bone being deposited upon their surfaces, reach the transplant and unite with it. It must be realized that new bone deposited on dead bone becomes firmly cemented to it, just as the new bone that is deposited on the calcified cartilage on the diaphyseal side of the epiphyseal plate becomes firmly cemented to the cartilage. This step in the history of a compact-bone transplant is illustrated in Figure 15 (second drawing), which shows that new trabeculae from the host have firmly united with the dead bone of the transplant. It is also obvious in this illustration that the osteogenic cells and osteoblasts from which these new trabeculae arose came from some little distance behind the dead edge of the graft bed.

After the transplant has become united to its host, it must slowly be resorbed and replaced with new bone. Resorption occurs in two general sites: (1) on the outer surfaces of the transplant in between areas where trabeculae of new bone have become cemented to it, and (2) on the inner surfaces of Haversian canals (Fig. 15, lower half).

It is to be appreciated that functioning blood vessels are just as necessary for the resorption of bone as they are for the deposition and maintenance of the life of bone. Accordingly, little resorption can occur from the inner surfaces of the Haversian canals of a transplant until there are functioning blood vessels in these Haversian canals. Since the blood vessels in the Haversian canals of a compact-bone transplant, unlike the blood vessels of a skin graft, do not survive transplantation, because of the difficulties of their being maintained by diffusion phenomena, they die and must be replaced by new ones which grow from the host into the Haversian canals of the transplants. This takes a considerable length of time. In some experiments performed by Dr. F. R. Wilkinson, in which the writer collaborated, Dr. Wilkinson transplanted blocks of compact bone to tibial defects in a series of dogs which were sacrificed at suitable times to provide examples of compact-bone grafts that had been in position for from one to eight weeks. As the dogs were sacrificed, their blood vessels were perfused and injected with gelatin and India ink by the same general procedure that Dr. Cloutier and the author had used to study the vascularization of skin grafts. Sections were then prepared from the sites of the transplants; and we found that it was not until a compact-bone transplant had been in place for four weeks that injection mass, and hence new blood vessels, appeared in the Haversian canals in the more central parts of the transplant, and even then, the injection mass was not seen in all the Haversian canals.

The advance of new blood vessels into the Haversian canals of the transplant is associated both with the resorption of dead bone from the canals, which widens them, and with the deposition of new bone on the sides of the canals, which narrows them again. The same two processes operate simultaneously on the exterior of the transplant and also at the dead edges of the graft bed, and so before long the transplant and the edge of the bed both become a conglomerate of living and dead bone (Fig. 15, lower half). Eventually

nearly all, if not all, of the dead bone is resorbed and new bone is substituted for it; but this takes considerable time because the dead bone must always be resorbed from a *free* surface and the new bone deposited on a *free* surface. This, I believe, is the actual process at work in what has been termed the "creeping replacement" of a transplant. It is very doubtful, in my opinion, if creeping replacement entails any resorption at surfaces between new and old bone, with the new pushing by means of interstitial growth — which would be the only kind possible under these circumstances — into the old.

As the dead bone of a compact-bone transplant is irregularly eroded at different sites around its outer surface, and as its Haversian canals become opened up by resorptive processes occurring within them, it tends to resemble cancellous bone as much as it does compact bone. But the deposition of new bone on all these surfaces eventually takes precedence over resorptive phenomena, and so it once more begins to resemble compact bone, thus providing another illustration of the fact that the filling in of spaces surrounded by trabeculae converts cancellous bone to compact bone.

Transplants of Cancellous Bone

It might be thought that the bone cells in a transplanted cancellous trabecula would have a much better chance of surviving transplantation than the bone cells in a block of compact bone. No bone cell in a small cancellous trabecula is very far away from a free surface, and when a trabecula is transplanted, the free surface could conceivably be bathed in tissue fluid. But the canalicular mechanism for diffusion is evidently so inefficient that, even though a cancellous trabecula is transplanted into an area close to functioning capillaries, nearly all the bone cells of the trabecula die. Dr. Stuart Gordon and the author, in an extensive experiment[1], followed the day-to-day appearance of autogenous cancellous fragments transplanted into both bone defects and muscle, and have concluded that, for all practical purposes, the cells in transplanted cancellous fragments fail to survive transplantation and that hence the ultimate fate of the substance of the transplanted bone is resorption.

Although the bone cells of cancellous fragments survive transplantation little better than the cells of compact bone, the possibilities with regard to the survival and growth of the covering and lining cells of cancellous fragments are much greater than those of compact bone. The first reason for this is that cancellous trabeculae are completely covered with osteogenic cells and osteoblasts and, since the trabeculae themselves are small, there is a relatively high proportion of surface cells to bone cells in cancellous bone. This is in contrast to compact bone (and in particular to chips from adult compact bone) wherein the proportion of surface cells to bone cells is very low. Accordingly vast numbers of surface cells are available when cancellous trabeculae are transplanted and, since the surface cells cover all aspects of the trabeculae, they face in every direction and so are able to take advantage of such nutritive tissue fluid as may exist in the site to which they are transplanted.

It should be realized, of course, that even without any of the surface cells of cancellous fragments surviving transplantation, cancellous fragments serve a very useful purpose in bone defects. This is because they stimulate the osteogenic cells, osteoblasts, and undifferentiated marrow cells of the host bone to grow into their midst and lay down bone on many of their surfaces. By this means the dead transplanted fragments become incorporated into a new network of cancellous bone which connects them with the bone of the host. The dead fragments, however, do not persist indefinitely in such a network, because resorption begins immediately on those of their surfaces which are not covered with new bone. Consequently in such an area new bone is frequently seen to be deposited on one surface of a transplanted fragment while resorption occurs on another. The continuance of both these processes sooner or later leads to the formation of a network of cancellous bone in the area, all of which is new.

It is obvious from the foregoing that cancellous fragments, even if both their bone cells and covering cells all die on transplantation, can serve a useful function in acting as objects for replacement. Acting in this capacity, they can conduct osteogenesis from all sides of a defect to its center. Each successive fragment acts as a fresh stimulus to the wave of osteogenesis that advances into the defect from its edges. Without the fragments the wave of osteogenesis from the edge of the defect might very well subside before the defect were filled; hence an important function of transplanted bone, whether it be compact or cancellous, is to stimulate its replacement by cells from the host and, since it acts in this fashion, it can be used to conduct osteogenesis from one point to another. Since cancellous bone is not of such a dense structure as compact bone, it can be invaded more easily and hence it can conduct waves of osteogenesis more rapidly than compact bone.

In addition to performing the function described above, cancellous fragments can perform another function under very suitable circumstances,—that of setting up new centers of osteogenesis. They can do this if they are transplanted into living tissue where there is a sufficiently good capillary bed to provide their surface cells with adequate tissue fluid. In order to prove that their surface cells can survive transplantation and give rise to new bone, the common experiment performed is to transplant them into muscle, where there are no other cells of a bony origin to confuse the issue. Dr. Stuart Gordon and the author [1-4] have done this several times and have repeatedly found that, when a mass of cancellous chips is placed in a muscle, the surface cells of the fragments that are around the periphery of the mass of fragments, close to functioning capillaries in the muscle, live and give rise to new bone which tends to grow toward the capillaries of the muscle.

In order to perform this second function, that of setting up new centers of osteogenesis, it should be emphasized that cancellous fragments must be placed in, or in very close contact with, living tissue, where sufficiently fresh tissue fluid is available from functioning capillaries to permit the survival of the surface cells of the fragments. Obviously, this requirement limits the surgical exploitation of this second function of cancellous transplants considerably; nevertheless, there are situations in which cancellous transplants can be used with some hope of some of their surface cells surviving. It is to be appreciated that the performance of this second possible function of cancellous transplants depends, not on their being of a small size, but upon the fact that cancellous trabeculae are covered with osteogenic cells and that in this respect they are very different from chips of compact bone which, except in the instance of chips taken from the compact bone of the very young [4], generally have naked surfaces. Chips of compact bone, therefore, while useful for other functions, are infinitely inferior to cancellous chips for the purpose of setting up new centers of osteogenesis.

It could be argued that chips of cancellous or compact bone have still another function, that of inducing bone formation by metaplasia from fibroblasts. Dr. Stuart Gordon and the author [4] recently investigated this matter by studying the fate of thrice-fast-frozen-and-thawed autogenous cancellous fragments, transplanted into muscle. In contrast to untreated fragments, about which we found some new bone in each animal, we found that no new bone developed in association with any of the thrice-frozen-and-thawed fragments. Since the repeated fast-freezing of a tissue probably destroys its cells by physical means, and does not alter its chemical constituents nearly as much as other procedures which destroy cells, our experiment shows, we think, that the bone which forms around cancellous fragments transplanted into muscle originates from the covering cells of the chips and not from fibroblasts by metaplasia. This experiment, like many others, suggests that those who seek osteogenesis should, in our present state of knowledge, continue to put their trust in the cells that cover and line bone surfaces and their close relatives in the bone marrow, rather than on cells such as fibroblasts which are designed for other functions.

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OSTEOTOMES FOR SPINE FUSIONS *

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The illustrated osteotomes were designed for spine fusion in which is used the "clothespin" self-locking type of bone graft originally described by Gibson and modified by Bos-

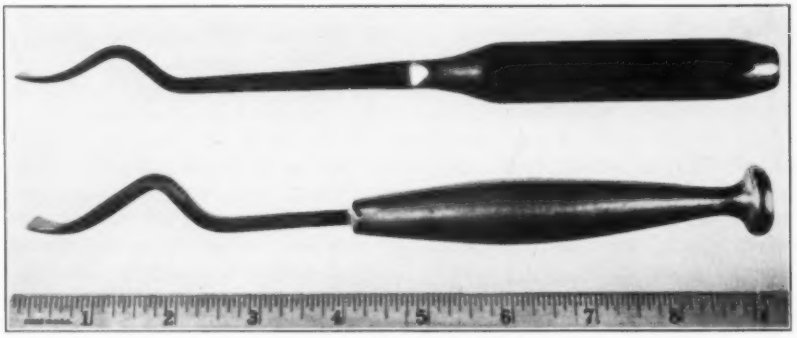

Fig. 1

Osteotomes for spine fusion, lateral view.

* Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the author are the result of his own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

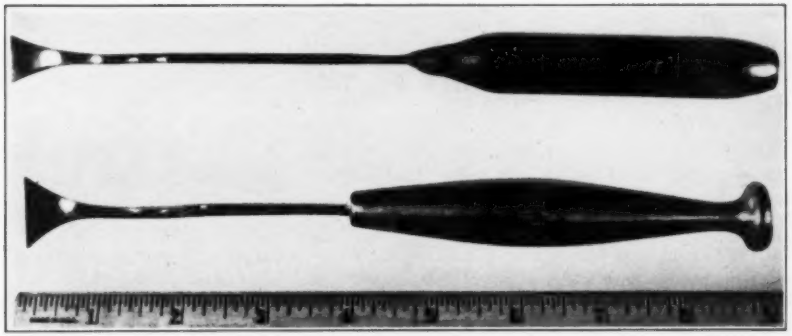

FIG. 2

Osteotomes for spine fusion, anterior view.

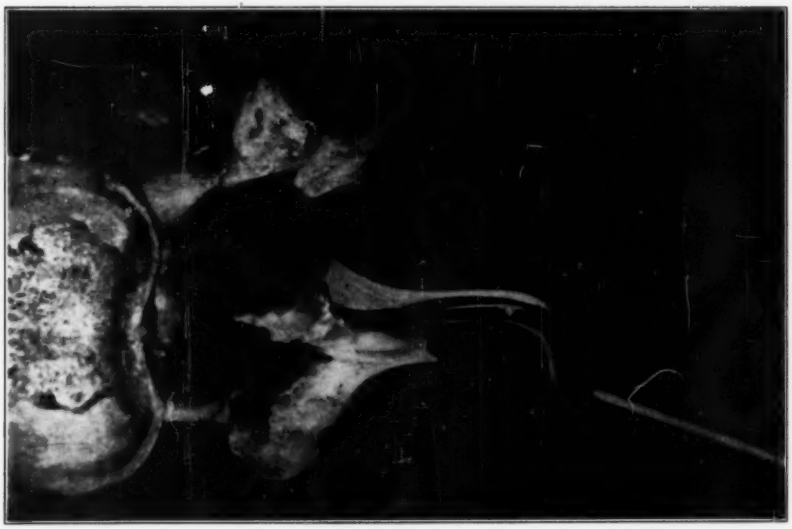

FIG. 3

Illustration showing how the curve of the instrument conforms to the shape of the spinous process and the lamina.

worth. The strength of the spinous processes determines the mechanical stability of the grafted area; therefore, the instruments have been designed to allow for the easy reflection of the cortex of the lamina without danger of fracturing a spinous process. The double bend in the shaft allows the osteotome to pass over the spinous processes without destroying the direct line of force from the handle to the curved cutting edge. The smaller instrument is useful in elevating flaps from the sacrum.

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AN IMPROVED APPARATUS FOR CERVICAL-SPINE TRACTION

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The usual apparatus for applying traction to the cervical spine, whether by means of a halter or by skeletal traction, consists of a pulley fixed by one means or another to the head of the bed, a length of traction cord, and a weight. With this type of apparatus, the direction of pull relative to the bed is fixed, and the back rest of the bed cannot be raised or lowered without changing the angle of traction relative to the cervical spine. The patient in this type of traction is often extremely uncomfortable; any means by which his position may be changed from time to time would add greatly to his comfort.

The apparatus illustrated here is intended to accomplish this purpose. It consists of a three-foot bar clamped vertically to the head of the bed, a six-inch bar clamped to the middle of the vertical bar and extended horizontally away from the bed, a three-foot bar extending vertically downward from the horizontal bar behind the head of the bed, four pulleys, about twelve feet of traction cord, and a weight. The apparatus is rigged as shown (Figs. 1 and 2). An idler pulley, *I*, is attached through a series of two pulleys to the back rest of the bed; it rises or descends as the back rest is raised or lowered, maintaining the direction of pull relative to the cervical spine practically constant. This allows the patient to be elevated from time to time as, for example, at meal times, without materially disturbing the traction. Figure 1 shows the back rest in lowered position and Figure 2 shows it elevated.

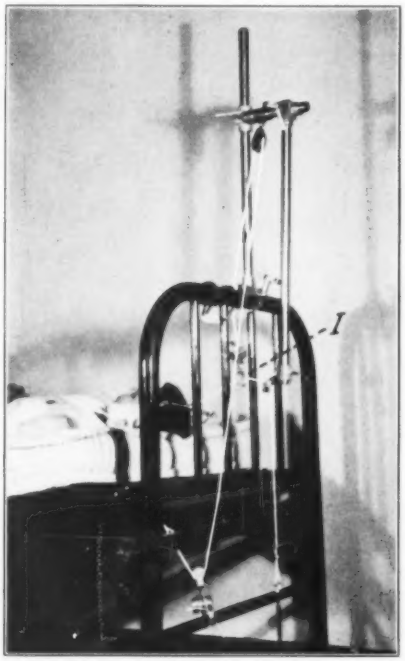

FIG. 1

FIG. 2

Although this apparatus has been used successfully in only two cases of halter traction, there appears to be no reason why it might not also be used with Crutchfield tongs or other forms of skeletal traction.

ABOVE-THE-KNEE SUCTION-SOCKET PROSTHESIS

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About a hundred years ago Debois D. Parmelee, of New York City, developed an artificial limb of the pylon type, which was held on the stump by suction. Since that time the suction-socket prosthesis has been used sporadically in England, Germany, Canada, and the United States. However, it was not until the fourth decade of the present century, when a satisfactory expulsion valve was invented, that it became popular in Germany. At the conclusion of World War II, the Surgeon General of the Army sent a Commission on Amputations and Prostheses to Europe to investigate new appliances. As a result of this investigation, this type of prosthesis was re-introduced into this country for greater use.

The suction-socket prosthesis eliminates the hip-joint and pelvic belt or shoulder harness. To a certain extent, it is held on the stump by a moderate degree of suction created in an air-tight socket; but mainly it is held on by the close anatomical fit of the socket. Thus the prosthesis gives greater freedom and comfort and allows unrestricted motion in the hip. The suction socket also permits improved control and position sense.[2] Generally speaking, the conventional type of prosthesis permits only flexion and extension movement; occasionally, however, some hip hinges may permit abduction and adduction, but none will permit rotation, which is the most important movement in the hip for proper locomotion. In the conventional type of socket, this movement is compensated for by alternate oscillations of the pelvis.

FIG. 1

The average shape of the brim of a suction-socket prosthesis is shown. Note the protuberance on the lateral wall.

Because of the close contact between the skin of the stump and the socket during all phases of locomotion, the prosthesis feels more like an integral part of the body. The piston-like action of the stump in the socket, so common in a conventional prosthesis, is markedly reduced. This allows for greater toe clearance and a smoother gait. In addition, a suction-socket prosthesis dispenses with the need of wearing stump socks and reduces the adductor roll so frequently seen in those who use the standard prosthesis.

The size, outer shape, appearance, and the actual relations of the suction-socket prosthesis to the body are much the same as those found in the standard prosthesis.[5] The socket should conform closely to the anatomy of the stump. This close fit is essential because the prosthesis is used on a physiological basis, and it is activated and controlled by the remaining muscles of the stump. It should fit snugly to maintain the air-tight seal, but should not fit so tightly that it restricts the action of these muscles or interferes with circulation.

The socket has a more rectangular shape than a conventional prosthesis (Fig. 1) and may be modified to conform to the needs of the individual. The medial border should be just below the level of the ischial seat. The height of this border varies with almost every patient and depends upon the condition and activity of the adductor muscles. Stumps

FIG. 2-A

FIG. 2-B

A trial prosthesis usually has excessively thick walls to allow for careful fitting and to permit adjustment while the stump grows. Compare with photograph of the same patient wearing a finished prosthesis.

with muscles which are atrophied but able to withstand the pressure of the socket are provided with a higher medial side. The adductor groove at the medial anterior angle should be narrow enough to maintain the air seal but wide enough to receive the tendons of the adductor longus, the adductor magnus, and gracilis without undue constriction. Too tight a fit will cause pain, and will tend to rotate the foot outward at the heel strike.

On the anterior side at the femoral triangle, pressure should be avoided for it may cause impaired circulation and oedema of the stump. The lateral side should fit at a higher level than any other part of the prosthesis and should extend to the position of the greater trochanter. The lateral side should also be so constructed as to create firm pressure. The highest point on the socket should be anterior to the greater trochanter and should not interfere with flexion or abduction. Usually, the lateral wall shows a protuberance on the inside of the socket; this is important as a stabilizer in walking, especially in stumps with flabby or atrophied muscles. This protuberance also stabilizes the ischial tuberosity on the ischial seat and prevents rotation of the prosthesis.

The posterior border is the main weight-bearing part of the socket and usually expands into an ischial seat and provides a relief for the glutaeus maximus. The size of the ischial seat varies; it must, however, be so adjusted to each individual that no slipping of the ischial tuberosity occurs. It is at present becoming evident that the ischial seat should

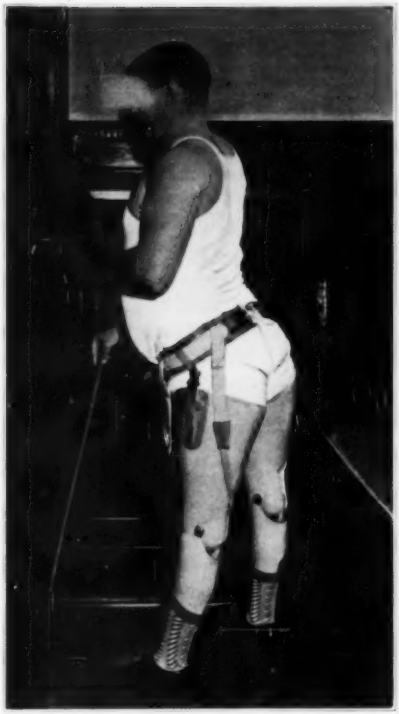

FIG. 3-A

FIG. 3-B

Photographs of a bilateral above-the-knee amputee. In Fig. 3-A he is shown wearing a conventional type of prosthesis and in Fig. 3-B, a suction-socket prosthesis. Note the change in posture a suction-socket prosthesis induces by the elimination of excessive lumbar lordosis.

have its weight-bearing surfaces sloping slightly toward the inside of the socket. Since the burden of weight-bearing will be by the glutaeus maximus, in a number of patients with well-developed muscles it may be necessary to eliminate the ischial seat.

The size of the ischial seat required can be determined by placing a finger on the ischial tuberosity and having the amputee contract the muscles of the stump and at the same time extend the stump as far back as possible. This will be the position of the stump at the end of the stance. The hamstrings, which arise in this area, will be felt pressing against the fingers. In most cases, it is possible to determine the size of the space between these muscles and the tuberosity of the ischium. The size of this space will roughly indicate the size which the ischial seat should be made. In some cases, however, the finger may be pushed away entirely by the hamstrings. Patients with such well-developed muscles will not tolerate ischial seats and for them a plug fit should be recommended.

The end of the stump must be free and should not bear weight (Figs. 2-A and 2-B). To provide adequate space for the automatic expulsion valve, the socket should extend at least two inches below the stump; this, however, is not mandatory.

INDICATIONS AND CONTRA-INDICATIONS

The suction-socket prosthesis may be prescribed for most above-the-knee amputees. It has been successfully fitted to stumps three inches long, and it has been used in weight-bearing amputations (Gritti-Stokes). In selected cases, Thorndike [3, 4] has had excellent

results with about eighty-seven per cent. of his patients. In general practice, Aldes found that a suction-socket prosthesis could be used for about seventy-five per cent. of all above-the-knee amputations. Because of the improved function, control, and fit, the suction-socket prosthesis is especially indicated for those who have impaired function of the other extremity, such as a stiff knee, paralysis, or deformity, and for those who have undergone bilateral amputation (Figs. 3-A and 3-B). In these patients the suction socket, by decreasing the piston action of the stump, increases the toe clearance and facilitates locomotion. Finally, the elimination of the pelvic belt makes the suction socket especially suitable for patients who have colostomies, pendulous abdomen, or painful scars at or near the crest of the ilium.

Contra-indications for the use of the suction-socket prosthesis are any active bone infection (osteomyelitis), deep-channeled scars near the brim of the socket, which would interfere with the maintenance of an air-tight seal, any serious skin condition which cannot be controlled with proper treatment by a dermatologist and which may be aggravated by suction. As a general rule, chronic boils, especially in the adductor region, are not contra-indications; neither is chronic peripheral vascular disease a contra-indication. As a matter of fact, the suction socket, on ambulation, acts very much on the same principle as passive vascular exercises,—it facilitates circulation by alternating negative and positive pressure.

PROBLEMS IN THE ALIGNMENT AND FITTING OF THE PROSTHESIS

The alignment of the suction-socket prosthesis is the most important factor to be considered in the fitting of the prosthesis. The knee and ankle joints of the prosthesis should be carefully adjusted to the required body axes of the individual. This alignment must be correct for the proper control of the prosthesis and the comfort of the patient while wearing it. The knee joint should be aligned with the axis of the body in three planes. The joint should be placed transversely and at right angles to the line of progression of the limb and not of the socket, and it should be placed horizontally in such a manner that the medial and lateral ends of the joint are at an equal distance from the ground.

In an average person, during weight-bearing, a line drawn through the center of the head of the femur will bisect the center of the knee joint at an angle of 87 degrees. Should the relations of the prosthesis to the axis of the body be not correct, the prosthesis, during locomotion, will have a definite whip. Meticulous alignment, therefore, is necessary (Fig. 4).

In the suction-socket prosthesis, poor alignment cannot be adjusted as easily as it can be in a conventional limb, in which a slight change in the hip hinge will make the fault less apparent. In general, the alignment of the suction-socket prosthesis must be evaluated on the basis of observation while the amputee is standing, walking, sitting on both hard and soft surfaces, and while he holds his stump suspended, as he would do when entering or leaving a car. It is often found that a prosthesis may be perfectly satisfactory in performing one of these actions and yet totally unsatisfactory for some other function.

Although it is possible to obtain a correct fit at the first fitting, it is not the rule. The vast majority of patients are fitted by a "trial-and-error" method whereby the socket is corrected as complaints arise. The process takes several months and it cannot be assumed that the socket is fitted correctly until nine to twelve months have elapsed. A poor or improperly fitting socket can be corrected in the majority of cases.

When a prosthesis is analyzed in regard to the correctness of the fit and the alignment, it is advisable to follow a routine based on both objective and subjective findings. One suitable method of undertaking such an analysis is a study of the patient's history and his complaints, and an analysis of the alignment of the prosthesis while the amputee is standing, walking, and sitting. Studies of the positive and negative pressure in the suction socket should be made, together with an examination of the end of the stump through the valve opening, an examination of the stump out of the prosthesis, and a comparison of the

size of the stump with the size of the socket. Specific questioning of the patient in regard to his history and complaints will generally indicate the source and the location of any trouble. It has been found that the most frequent complaint is of pain. Another frequent complaint is sore muscles, caused by fatigue due to prolonged continuous overuse without rest. This condition is relieved by rest and warm baths.

In the initial phases of fitting, a poor lacquer coating on the inside of the socket may cause both pain and skin irritation. All sockets should be finished smoothly and lacquered inside before fitting. This prevents pain and "too large a fit". Pain may be caused by the brim of the socket being too thin and thus too sharp. A painful ischial-seat area should be evaluated thoroughly. This area usually becomes sore in amputees not accustomed to ischial weight-bearing. If it persists, other causes have to be considered:

FIG. 4

FIG. 5

Fig. 4. Alignment of a trial prosthesis. This prosthesis is slightly short, and the prosthetic foot shows excessive weight-bearing on the lateral border.

Fig. 5. Felt heel and sole lifts are used for the adjustment of the length of the prosthesis. These are modified easily as the condition warrants. After a fair trial of about two to three weeks, the limb is permanently lengthened.

1. Too wide an ischial seat may cause a slipping of the tuberosity to either side while the wearer is sitting. Too wide an ischial seat may also cause a jabbing sensation or a marked pressure pain in the area of the tuberosity at the end of a step. To prevent this, the weight-bearing surface may be sloped slightly inward.

2. Too great an anteroposterior diameter of the suction socket may result in the ischial tuberosity being pushed forward off the ischial seat.

3. Too sharp an ischial seat may cause pain and make a sharp indentation in the skin because of overstretching. This may be corrected by sloping the ischial seat.

4. Too large a gluteal relief will shift all of the weight onto the ischial tuberosity. In patients with good glutaei maximi, the entire seat may be eliminated.

Pain in the crotch is usually due to crowding the muscles in the anterior medial angle of the stump. Such pain may be relieved by enlarging the portion of the socket in contact with this area. A smooth finishing of the upper two or three inches of the outside surface of the medial wall of the socket during rough fitting will decrease the friction in the crotch and will thereby decrease pain and facilitate locomotion.

An analysis of the alignment is made while the amputee is wearing his prosthesis (Fig. 5). At first, he is examined in a standing position. Here the height of the brim, the

pressure areas, and tightness of the fit of the socket should be noted. An excessive roll of skin above the brim is due to the socket being too small, not permitting the skin of the stump to be drawn down into the socket. This is relieved by widening the socket, especially those portions of it which are over bony prominences. Following this, gait is analyzed and all the abnormalities are noted. The following are the most common faults observed in the gait of a wearer of a prosthetic limb:

1. A whip of the knee in the swinging phase of a step, associated with rotation of the leg as the heel strikes the walking surface, due to malalignment of the knee axis;

2. Rotation of the foot at the heel strike or at the toe-off may be caused by too tight a fit of the socket in the adductor region, by incorrect knee alignment, or by an ankle joint placed in the wrong axis;

3. Medial lateral instability during stance phase is usually due to incorrect alignment of the foot, especially of the plantar surface, and to malalignment at the knee.

Next, the amputee is examined in a sitting position. It is important to have him assume a reclining or slouching position, which is the usual and common position assumed in an easy chair or a car. Here, it is important to note if the air seal is maintained and if the posterior wall of the prosthesis is properly shaped so that it will not cause outward rotation.

Following the analysis of alignment, pressure studies should be made. The average pressure in the socket is between +1.5 and −0.5 pounds per square inch, although pressures up to ±3 are not abnormal. High negative pressure usually indicates a tight fit.

After the pressure studies, the valve is removed and a finger is inserted into the valve housing to feel the stump end and to determine the condition of the stump.

The prosthesis is then removed and the stump is examined for complications:

1. A common complaint is the discoloration of the skin at the end of the stump due to capillary congestion which results from pressure at the brim or an uneven fit of the socket. The usual discoloration develops as an elliptical area embracing the end and medial aspect of the stump. As time goes on this may fade to a lighter hue or it may endure as a pigmented area.

2. Swelling or oedema is due to a tight fit of the middle and upper parts of the socket or to an overuse of the limb. In a growing stump, it may be due to the fact that muscles have increased in size. The degree of oedema varies from a fairly slight increased thickening of the pinched skin to complete choking with a "blow-out". Choking may also be caused by the cone-shaped lower part of the socket. Removal of the socket for a period of time and elevation of the stump with the patient lying on his back are effective methods of treatment. Compression bandaging may be of value if pressure is applied evenly or graded so that the proximal end is not constricted and the pressure is applied distally. The socket should be re-checked and the areas causing tightness should be corrected.

3. Skin irritation, especially in the adductor region, is a common complaint. Although this, usually, does not interfere with the wearing of the prosthesis, the adductor channel may have to be relieved. Skin irritation must be treated promptly by proper hygienic procedures. A mild disinfectant, such as 0.5 per cent. formalin, can be applied. In cases of fungus, the author has had good results with a fungicide ointment applied at night.

4. Petechiae or small subcutaneous hemorrhages may be due to excessive negative pressure created by a faulty valve. If the petechiae are numerous, then increased fragility of the capillaries is to be suspected. This can be determined by a petechiometer. Usually, fragility is due to vitamin-C deficiency.

5. Fissures of the skin caused by the tuberosity sliding or rolling off the seat excessively are occasionally found posteriorly in the region of the ischial seat. A careful evaluation of the seat, although difficult, is necessary. When lipstick is used to mark the tender or affected areas on the skin, these markings will be transferred to the socket when the patient puts on his prosthesis. The exact source of the irritation will thus be indicated.

PROBLEMS OF TRAINING AND REHABILITATION

Preprosthetic Training

The preprosthetic exercise-training program for the prospective suction-socket wearer does not differ materially from that which any other above-the-knee amputee undergoes. The purpose of the training program is to develop a well-functioning stump,—one which will be able to utilize to the fullest possible extent the prosthesis. At first, the stump is bandaged in order to obtain a more cylindrical shape. It is only logical to correct all defects present in body alignment and to secure a normal range of motion of all joints.

Muscle balance must be established. In a recent amputee who has not worn a prosthesis, this is not too difficult; but for those who have worn some type of conventional prosthesis, it may become a problem. These amputees have developed a gait which is restricted by the pelvic band and hip hinge and have thus set up a walking pattern which is hard to change. The main characteristic of such a prosthetic-gait pattern is the substitution of pelvic motion for the rotation of all segments of the extremity which occur in normal locomotion.

There is no routine set of exercises which can be prescribed, just as there is no consistent pattern of muscle imbalance. The basic principles of the preprosthetic exercise program are: (1) prevention of contractures, (2) maintaining joint range, and (3) correcting individual muscle weakness. The exercises should be specific and should avoid exercising antagonists of weak muscles until muscle balance has been restored. The hip joint should be put through full range of motion in all directions,—especially, hyperextension of the thigh which is most frequently forgotten but which is necessary for proper locomotion.

Special emphasis should be put on the exercising of the remaining portions of the long head of the biceps femoris, the semimembranosus, and the adductor magnus. This is accomplished by exercising the stump in an adducted and internally rotated position during extension. The glutaeus maximus muscle is exercised in extension and external rotation. Progressive heavy resistive exercises should be employed for increasing the strength of all stump muscles. The exercises must be executed properly, for otherwise they have little value and may even be detrimental to progress. In addition, preprosthetic training should develop good balance and body alignment. It should prevent and correct as much as possible such postural faults as the head forward position, kyphosis, lordosis, rotation of the pelvis or femur, and pronated normal foot.

Postprosthetic Training

After the prosthesis has been fitted and aligned, the patient is started on postprosthetic training, which usually requires from four to six weeks of concentrated effort. During the first phase (lasting about a week), the amputee learns to apply his prosthesis correctly. This is important in the suction socket, as the prosthesis will and must fit only in one position in order that the air seal be maintained, proper distribution of weight be made on the ischial seat, and the channels in the socket fit correctly over the respective tendons. If the application of the prosthesis is not correct, pain and skin irritation will result and the gait will be faulty.

The most important single factor in the developing of a fundamental walking pattern is the acquisition of body balance while the patient is wearing the prosthesis. In some patients, this sense of balance is easily obtained; in others, it may require intensive practice. This sense of balance is harder to obtain in those who wear the suction-socket prosthesis because of the elimination of such support as the pelvic hinge and belt. At first, these patients may feel wobbly and insecure. Some such amputees may benefit from wearing a webbing belt which gives an added sense of security and which prevents undue rotation of the leg. The best type of belt is the Silesian band. This consists of a U-shaped metal strap which is attached to the top of the lateral socket wall and which encircles the region of the

trochanter. To this is attached a soft webbing belt which extends across the back of the pelvis, the opposite hip above the trochanter, and below the crest of the ilium. It is attached to the front of the prosthesis below the level of the trochanter and slightly to the medial side of the mid-line of the socket. Such support is particularly helpful in amputees with flabby stumps or with very short stumps.

At first, exercises in balance are carried out in a walker and before a full-length mirror. The amputee should observe himself in the mirror. The above-the-knee amputee must be able to extend his stump more than the normal individual in order to maintain correct pelvic balance. Pelvic balance may be disturbed because of the shift in weight-bearing from the hip joint to the ischial tuberosity and gluteal muscles in the suction socket. This causes a change in normal alignment of the body load and a posterior shift of the center of gravity. During walking the force of gravity, acting through this new center of gravity, tends to tip the pelvis forward. This is automatically compensated for by the amputee tilting his trunk backwards,—an action which may cause him to either sit on the ischial seat or walk with a lumbar lordosis. This is undesirable and should not be permitted to occur.

During the first week, the amputee is permitted to wear the suction-socket prosthesis from one-half to one hour twice a day. After each such period, the stump is checked for any appearance of complications. As soon as the stump becomes toughened to the use of the socket, the time during which the prosthesis may be worn is gradually increased.

The second phase of postprosthetic training is devoted to teaching the amputee to walk. It is futile to believe that a few exercises will be sufficient for such re-training, for a good walking pattern is acquired only through intelligent walking practice. It must be emphasized that training specific muscle groups does not in itself create a new walking pattern; however, exercise for specific muscle groups is indicated when the function of any such group is inadequate. In general, the training is similar to that employed for the wearer of a conventional prosthesis, except that certain new motions, such as swinging and circling exercises for developing lateral and medial rotation, must be added to the routine. All exercises should be done with the pelvis held as stable as possible, and during these exercises the amputee should tighten the stump muscles. This will give the wearer better control of the prosthesis. With practice, tightening of the stump muscles will become automatic and the degree of contraction will vary with the movement performed. It should be pointed out to the amputee that conscious contractions normally should be used only for extraordinary motion; otherwise, conscious contraction of the stump muscles will interfere with rhythmic locomotion. Because of a lack of muscle control, in the early phase of training the amputee will have a somewhat wobbling gait, which consists of a medial rotation of the thigh during the swing phase followed by a sudden lateral rotation as the prosthetic heel strikes the ground. As confidence in the prosthesis develops in the wearer, this faulty gait usually disappears without any adjustment to the socket.

At first, level walking is practised. The patient then progresses to more difficult tasks, such as, turning, walking on soft and uneven ground, and stepping over obstacles. Following this, training is given in reciprocal and coordinated motion of all extremities and in endurance exercises.

The next phase is the rehabilitation of the amputee in the activities inherent in daily living. He should be taught to ascend and descend stairs, walk up and down ramps, walk backward and sideward, sit and arise from a chair or the floor, pick up objects, and step onto and off a curb. In this connection, it is necessary to instruct the patient to maintain negative pressure in the prosthesis and to hold the prosthesis on. If he feels that the prosthesis is becoming loose, he should step on it several times. This usually will be sufficient to create adequate negative pressure for holding the prosthesis securely in place.

During training, numerous defects of gait will become apparent. These defects must be corrected promptly to prevent them from becoming a habit pattern. The most common

defects are: incorrect spacing and timing, excessively long prosthetic steps, lateral deviation of hips, wobbling, and limping.

After the patient acquires a good gait, he may be discharged but should be followed at intervals of four to six weeks for about nine months. During the re-checks, an analysis of the fit and gait, as previously outlined, should be made. The effect of the suction socket on the stump should be carefully observed and any undesirable changes should be corrected.

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AN INSTRUMENT FOR THE EXTRACTION OF BONE SCREWS

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Screws which are placed in bone for the purpose of approximating fragments become firmly fixed with new-bone formation after a period of time *in situ*. Attempts to remove these screws by simply unscrewing them often leads to shearing off the heads of the screws, leaving the bodies firmly implanted in the bone. The surgeon is, therefore, faced with a difficult technical problem when the total removal of the screw is indicated.

The screws are usually constructed of a hard steel with high carbon, chromium, and nickel content to prevent corrosion. This composition makes it difficult to extract them by drilling them out or by using an "easy-out" device. Methods in use require that the extracting instrument penetrate the screw itself.

Usually, screws are removed by whatever method seems the most simple and the least likely to cause osseous defect and discomfort for the patient. Many surgeons drill around the screws in an attempt to loosen them sufficiently so that they may be unscrewed;

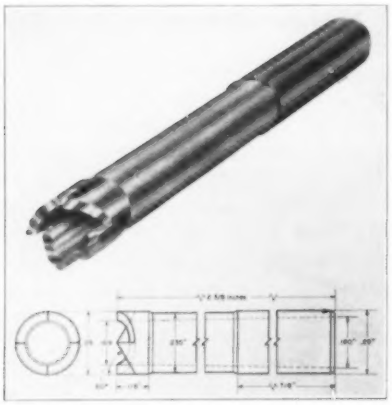

FIG. 1

FIG. 2

others chisel down through the top layer of bone and then extract the screws by unscrewing them with pliers.

Innovations in "new" types of screw heads, such as the "Phillips" head, offer no advantage in the removal of stubborn screws.

If the screw can be removed by simply being unscrewed, the extraction can be performed in only a few minutes; however, if the screws are stubborn, the procedure may easily take hours. To offset the latter possibility, we have designed an instrument which, we feel, will ensure the simplicity and speed of the operation.

The simplest way to extract a screw, the head of which has been sheared off, is not to attack the screw itself but to eliminate it in much the same manner as a core is removed from an apple. Thus a trephine was designed, using many of the principles employed in the construction of an oil drill. It was constructed of a high carbon tool steel which was heat-treated for hardness. The instrument was designed to accommodate the body of a "standard" bone screw. The internal bore at the cutting end will just accommodate the screw; the bore is then gently enlarged toward the grasping end of the drill. This internal tapering was designed to minimize binding of the bone-screw core upon the instrument. Externally, the cutting end is larger than the main body of the trephine,—a type of construction used to minimize binding by reducing the surface of the shaft of the trephine in contact with the bone. This subsequently reduces frictional heat. The grasping end of the drill is slightly enlarged to ensure a firm grasp of the instrument by the drill chuck (Fig. 1).

The pitch and angle of the teeth, as well as their number, have been carefully considered in relation to maximum strength and function.

USE OF THE INSTRUMENT

For the best results, the trephine should be used in conjunction with an electrically operated bone drill. The trephine is placed over the top of the bone screw and is activated by gentle downward pressure towards the bone (Fig. 2). If the process results in excessive heat, it may be diminished by either slowing or stopping momentarily the trephining process or by trephining under a sterile cooling solution.

Occasionally it may be necessary to remove the trephine from the bone to clean out the teeth.

When the procedure is completed, a gentle "give" will be felt on the drill. The screw and a small core of bone will generally lift out with the trephine. This core may be eliminated from the trephine by cleaning it out with a small metal rod. The resulting defect in the bone will be one-quarter of an inch in diameter.

VENOUS THROMBOSIS AS IT APPLIES TO ORTHOPAEDIC PATIENTS*

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Physicians generally, and particularly those who are concerned with the treatment of patients subjected to tissue injury, have become increasingly more cognizant of the importance of venous thrombosis. Before the introduction of antibiotics and chemotherapeutic agents to control infection and before the importance of blood-volume deficiencies was generally understood, physicians were primarily concerned with the treatment of infection and shock, because these two conditions were responsible for most of the deaths occurring after various types of trauma. At the present time, however, thanks to a rational understanding of conditions which produce shock and their detection and correction, and to the availability of antibiotics to control and combat infection, these two principal causes of death following trauma have been eliminated almost entirely. On the other hand, the incidence of venous thrombosis, in spite of all the work that has been done to prevent and control it, has increased steadily, so that intravenous clotting has become much more important than previously, not only because it has actually increased, but also because, with the control of shock and infection, it has become relatively more important.

In the Charity Hospital of New Orleans from July 1, 1938, to June 30, 1951, 647,868 patients were admitted, of whom 32,254 died. (Stillbirths are not included.) During this same period 168,279 operations were performed, not including those on the eye, ear, nose, and throat services. Thrombo-embolism was diagnosed in 1,223 cases, or one in every 529 admissions. During the same period, a diagnosis of fatal pulmonary embolism was made in 476 instances, of which 383 were confirmed by autopsy. Had autopsy been performed in all cases, the expected incidence of fatal pulmonary embolism would have been 1,130. Thus fatal pulmonary embolism was diagnosed once in every 1,361 patients admitted, and there was an expected incidence of one in every 573 patients admitted. Of the 186,279 patients operated upon, 106 died of pulmonary embolism; in seventy-two of these the diagnosis was confirmed at autopsy. Had autopsies been performed in all cases, the expected incidence of postoperative emboli would have been 212; thus fatal pulmonary embolism was diagnosed in one of every 1,757 cases operated upon and, presumably, occurred in one of every 878 cases operated upon.

Although the incidence may not seem, and in reality is not, particularly high, it is of significance that in the Charity Hospital, an institution in which the staff has been interested in thrombo-embolism for many years, the incidence of venous thrombosis and fatal pulmonary embolism has increased throughout the years. If the Charity Hospital series is divided according to three different time periods—1938 to 1942, 1942 to 1946, and 1946 to 1950—it is found that the number of cases of thrombo-embolism per 100,000 admissions increased from 131 in the first period to 194 in the second and to 241 in the most recent period. The increase in fatal pulmonary embolism was not quite so marked, as illustrated by figures for the three periods: sixty-one, sixty-eight, and eighty-nine respectively.

Although thrombo-embolism is believed to occur principally after trauma, it must be emphasized that it can complicate many other conditions, especially in persons with cardiac disease, particularly coronary disease. Venous thrombosis is a result of many factors, some of which are quite well understood while others are not. It is a disease largely of older persons. In the Charity Hospital series of 100,000 admissions, 254 cases occurred in adults, whereas only twenty-one per 100,000 admissions occurred in children. The difference in the cases with a fatal outcome was less marked, that is, 102 and seventeen per 100,000 admissions respectively. Although peripheral thromboses occur more frequently in women than in men, all cases of thrombo-embolism are somewhat more frequent in men, particularly fatal embolism. The relatively high incidence of peripheral thrombosis in women is undoubtedly due to the fact that women are more subject to phlegmasia alba dolens, which is so frequently a complication of childbirth. On the other hand, fatal pulmonary embolism occurs more frequently in men, because it is likely to be associated with coronary disease, which is much more frequently encountered in men than in women.

Venous thrombosis is usually one of two types which differ in their mechanism of production, clinical manifestations, prognosis, and therapy [5, 7, 8, 9, 10, 11]. For this reason it is imperative that in each patient the particular type of venous thrombosis be determined, in order that appropriate therapy be instituted. Venous thrombosis in thrombophlebitis is the result of changes in the vascular endothelium secondary to perivenous lymphangiitis resulting either from actual bacterial invasion or from the presence of toxins. Because of the inflammatory process in the endothelial lining of the vein, clotting occurs. The thrombus in such an instance is a white thrombus, firmly attached to the vein wall, and is not likely to become detached unless, as a result

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of suppuration, there is liquefaction of the clot; if this occurs, fragments of the softened clot can break off with the production of septic emboli. The diagnosis of thrombophlebitis (phlegmasia alba dolens) usually is not difficult because of the pain, frequent fever, swelling, and tenderness of the limb and the frequent whiteness and coolness of the extremity. The prognosis in phlegmasia alba dolens is good as regards life, except in the relatively rare cases of suppurative thrombophlebitis. However, in non-suppurative thrombophlebitis, there is a likelihood of persistence of sequelae which may plague the patient for the rest of his life.

Phlebothrombosis, on the other hand, develops much more insidiously. The clot is not the result of changes within the vascular endothelium, but is probably the result of two factors, one predisposing and the other precipitating. The predisposing factor is the increased coagulability of the blood following tissue injury. Apparently it is immaterial what causes the trauma, but as long as there is injury to tissue, changes in the blood constituents occur which favor clotting. Although the increased coagulability of the blood exists throughout the entire vascular tree, phlebothrombosis, with few exceptions, chiefly occurs in the veins of the lower extremity, particularly in the veins of the calf muscles, in the thigh, and in the plantar aspect of the foot. Slowing of the blood stream in these areas is the precipitating factor which favors the development of the clot. Because the clot does not occur as a result of irritation or inflammation of the vascular endothelium, it is not firmly attached to the vein wall; it is a coagulation thrombus which is similar to the clot that occurs whenever blood clots outside the body. Since it is not firmly attached to the vein wall, it can be detached easily with the production of massive fatal embolism or non-fatal infarction of the lung. Unfortunately patients with phlebothrombosis have few clinical manifestations or none; in fact, in over 40 per cent. of our cases of fatal pulmonary embolism, there was no clinical evidence of a previous thrombosis as determined either by the patient's complaint or by examination of his extremities or lungs[7]. The patient with phlebothrombosis is therefore a potential fatality and must be treated accordingly. Because of the great likelihood that the clot can become detached with the production of either non-fatal pulmonary infarction or fatal pulmonary embolism, ligation of the vein on the cardiac side of the thrombus is imperative as soon as the diagnosis is suspected. The prognosis in phlebothrombosis as regards life is grave unless prompt ligation of the vessel is done. However, if the patient is fortunate enough to survive without the development of pulmonary embolism, there is little likelihood of persistent sequelae.

If the above premise concerning venous thrombosis is correct, it would seem that the orthopaedic patient is an ideal candidate for the development of phlebothrombosis, because both factors—namely, tissue injury and circulatory stasis—are likely to be present. Although phlebothrombosis is not infrequent in orthopaedic cases, we think one of the reasons it does not occur more frequently is that the circulatory retardation resulting from immobilizing the extremity in plaster is at least partially nullified by dilatation of the arterioles and the consequent increased capillary *vis a tergo* because of retention of body heat by the cast. The following are examples of phlebothrombosis in patients with fracture:

Case 1. A colored male, aged forty-seven, sustained a fracture of the shaft of the right fibula after being struck on the leg with a heavy piece of machinery. The fracture was reduced and a walking cast was applied the next day, but the patient was unable to walk on the cast and relied entirely on crutches. About four weeks later, soreness developed in the right calf and persisted. Malaise developed two days later, at which time the patient was seized suddenly with severe pleuritic pain on the right side and shallow rapid respirations developed. Fine râles and decreased breath sounds were present in the right base and the abdominal muscles presented marked splinting. Superficial femoral ligation was done a few hours later; this was done on the right side only because of technical difficulties. Although no clot was demonstrated at the time of the ligation, it was felt that a clot had been present at least in the calf and that a portion of it had broken off with the production of pulmonary infarction. Recovery was satisfactory.

Comment

Although in this case unilateral superficial femoral-vein ligation was sufficient to prevent further pulmonary infarction, it is unwise to limit ligation to one side, because of the frequent bilateral involvement. We are convinced that, if femoral-vein ligation is indicated, either both superficial veins or the inferior vena cava should be ligated.

Case 2. A white male, aged fifty-three, was struck by an automobile and suffered a fracture of the head of the right fibula and avulsion of the tibial spine. The fractures were reduced, the leg was immobilized in a posterior plaster mold, and four days later a toe-to-groin cast was applied. The patient was allowed to go home but was readmitted because of a pleuritic pain, hacking cough, and a temperature of 102 Fahrenheit. Dullness and bronchial breathing were present at the right base and later some blood-stained sputum was expectorated. The patient was believed to have pneumonia and was treated with antibiotics, with gradual improvement. Before ambulation was allowed, however, the possibility of pulmonary embolism was considered and the cast was removed to allow complete examination of the leg. Nothing abnormal was found and, although the condition was diagnosed as phlebothrombosis with pulmonary infarction, it was believed that the thrombus had produced sufficient inflammatory reaction of the vein wall to fix it to the wall of the vessel. The morning after ambulation, the patient was awakened by a sharp, stabbing pain in the right chest. Rusty

sputum was expectorated and the temperature rose to 101 degrees Fahrenheit. Examination of the legs revealed no abnormality, but immediate bilateral superficial femoral-vein ligation was done. A clot was found on the right side and was removed by suction. Because of the proximal extension of the thrombus, heparin was employed for several days postoperatively. The patient made an uneventful recovery. He was examined one month after discharge and showed no signs of circulatory disturbance in the legs.

Comment

Two non-fatal pulmonary infarctions occurred in this case and extensive phlebothrombosis was present in the right lower extremity without any clinical evidence of its presence. Complete recovery followed bilateral superficial femoral-vein ligation.

A typical example of phlegmasia alba dolens or femoro-iliac thrombophlebitis is the following:

Case 3. A male, thirty-five years old, had suffered a fractured pelvis while playing football fifteen years previously. He was treated by traction and bed rest. Two weeks after the injury, pain and swelling developed in the right lower extremity. This subsided and the fracture healed. He later noted an enlargement of the superficial veins on the right side, and two to three years later an ulcer first developed above the medial malleolus. This was treated by high saphenous-vein ligation with prompt healing. During the ensuing years recurrent ulcerations occurred which were treated with varying degrees of success by multiple vein ligation and injection. Mild to moderate swelling was well controlled by elastic bandages. Shortly before admission several new ulcers had developed and failed to respond to the usual measures. On examination the right lower extremity was found to be somewhat larger than the left. The superficial veins had been largely obliterated. Three small superficial ulcers were present just above the ankle, surrounded by pigmented and slightly indurated skin. The right foot was cool and moist. The patient volunteered that sweating had been more noticeable on the right side for some time. Pulsations of the dorsalis pedis and tibialis posterior arteries on the right were diminished and, because it was felt that an associated vasospasm was responsible for the decreased circulation, a right lumbar sympathectomy was performed. There was an excellent return of warmth and increase of pedal pulses. The ulcers healed rapidly.

Comment

Generally such satisfactory results are not obtained by sympathectomy, but more extensive procedures are necessary.

Arteriolar spasm is prominent in acute thrombophlebitis and is, we believe, responsible for most clinical manifestations, such as pain, coolness, and white discoloration of the extremity and persistence of oedema and fever. Prompt relief of arteriolar spasm by procaine regional sympathetic block during the acute attack causes rapid subsidence of the clinical manifestations and usually prompt and complete recovery[6]. Although persistent arteriolar spasm can occur as a postphlebitic manifestation in the untreated case, it is unusual to secure such rapid and complete recovery as was secured by sympathectomy in this case.

The cause of the oedema which so frequently follows trauma of the extremities has produced considerable concern among investigators. Leriche believes that trauma stimulates the sympathetic nerves, producing active vasodilatation which causes oedema. Adams-Ray and Hjelmstrom believe that traumatic oedema is the result of dysfunction of the sympathetic nervous system which causes spasm on the venule side of the capillary bed, resulting in oedema. They, like Leriche, believe that this can be relieved by interruption of sympathetic impulses and have shown that, following sympathetic block, there is a decrease in the diameter of the oedematous extremity and an increase in the size of the opposite, normal extremity. The fact that post-traumatic oedema and other sequelae similar to those seen following thrombophlebitis can occur without antecedent phlebitis is illustrated by the following case which was previously reported[2].

Case 4. A white man, forty-eight years old, at the age of twenty-three had sustained severe trauma to the right leg with avulsion of a large amount of tissue. When first seen by us, he had persistent oedema and repeated ulcerations in the involved extremity. Ambulatory venous-pressure determinations, however, indicated that the venous system was normal. Because a carcinoma had developed on the basis of his ulcer, an amputation was done. Dissection of the extremity confirmed lack of involvement of the venous system.

Although there are undoubtedly many cases in which a post-traumatic oedema develops which is not the result of associated or antecedent thrombophlebitis, we are of the opinion that most of the persistent sequelae following trauma are the result of an antecedent thrombophlebitis. We have observed many patients with post-traumatic sequelae in whom subsequent examination of the venous system showed definite involvement of the deep veins, indicating that a severe antecedent phlebitis had existed. The belief that traumatic oedema is likely to be the result of thrombophlebitis is shared by Leger and Frileux.

In all patients subjected to trauma, including orthopaedic patients, the possibility of venous thrombosis must be considered. This is particularly true in older persons in whom the incidence of venous thrombosis is much more common than in younger patients. If evidence of thrombophlebitis develops in which the symp-

toms are due largely or almost entirely to vasospasm, prompt improvement results if active vasodilatation is secured by anaesthetization of the regional sympathetic ganglia. Not only will there be a rapid subsidence of the clinical manifestations as a result of this therapy, but usually sequelae can be prevented. These sequelae, such as postphlebitic oedema, postphlebitic ulceration, and recurrent erysipeloid infection, are frequently very disabling. On the other hand, in patients with phlebothrombosis who have few or no clinical manifestations, prompt radical therapy to prevent the clot from becoming detached and being carried to the heart and pulmonary arteries is imperative. Although it has been suggested that such cases can be treated satisfactorily by the administration of anticoagulants, it is our firm belief that this method of therapy not only is not efficacious but is also hazardous, because we have repeatedly observed subsequent pulmonary infarction, fatal embolism, or both, after adequate anticoagulant therapy had been employed, as illustrated by the following case.

CASE 5. A male, aged thirty-six, one month previously had sustained fractures of the left tibia, pelvis (ascending and descending rami, left pubic bone, and ascending ramus of the right pubic bone) comminuted fracture of the left clavicle, and left acromioclavicular dislocation. Progress had been satisfactory until, without warning, pain in the chest developed and a diagnosis of pulmonary infarction was made. Heparin and dicoumarol therapy was instituted. Five days later, with a 20 per cent. prothrombin level, massive nonfatal pulmonary embolism developed. The anticoagulant therapy was intensified until the prothrombin value was 10 per cent. Although there was no evidence of phlebothrombosis on examination of the lower extremities, venous ligation was elected. After intensive therapy with whole blood (2,000 cubic centimeters) and large doses of synthetic vitamin K, the prothrombin level was elevated to 30 per cent. Because of the extensive pelvic fractures, it was decided to perform an inferior vena cava ligation rather than superficial femoral-vein ligation. Following caval ligation the subsequent progress was satisfactory except that the patient bled from his nose, mouth, bladder, and rectum for three days. Three months later his prothrombin was only 50 per cent. of normal! Recovery has been complete with no disability. He has been able to return to his former occupation and to carry on as well as before his injury or better.

Comment

This case illustrates the insidious onset of phlebothrombosis and the difficulty in diagnosis as well as the ineffectiveness of adequate anticoagulant therapy (even to the point of producing a hemorrhagic tendency). Although the main venous channel draining the pelvis and lower extremities was interrupted in order to prevent additional emboli from being carried to the heart and lungs, there is no residual disability, demonstrating the complete innocuousness of inferior vena cava ligation in many cases. The residual manifestations following caval ligation are the result of the antecedent or accompanying inflammatory reaction and not the result of the interruption of the vein.

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FREDERICK A. JOSTES

1895–1952

Frederick A. Jostes was born in St. Louis, Missouri, on August 14, 1895. He obtained his early education in the St. Louis schools, receiving the degrees of Bachelor of Science and Doctor of Medicine from Washington University in 1918 and 1920 respectively. At Barnes Hospital, in 1921 and 1922, he was Assistant Resident in Surgery. During 1923 he served as Assistant in Surgical Pathology at the Washington University School of Medicine. In 1924, the year in which the Shriners' Hospital for Crippled Children was opened in St. Louis, he became its first Resident Surgeon. During the years 1925 and 1926, he attended the various orthopaedic clinics in Austria, England, France, Germany, Italy, and Switzerland, working with and learning from the orthopaedic masters of that time, including Sir Robert Jones, Putti, Rollier, and others. In 1927 and 1928 he was Professor of Orthopaedic Surgery at the University of Missouri, and during those years he helped to organize a state-wide crippled children's program. Thereafter he returned to his alma mater, Washington University School of Medicine, where in 1935 he became Assistant Professor of Clinical Orthopaedic Surgery.

His personality was well developed and had more facets than space allows one to dwell upon. The humanity which is seen in most surgeons of mark was in him a clearly etched quality. He valued the worth of natural phenomena, so that his home just above the confluence of two great rivers—overlooking the lowlands along the Missouri and, beyond, the high cliffs of the Mississippi—was developed to show every advantage of terrain, skillfully nurtured gardens, and distant vistas; and to give pleasure at frequent social events to his numerous friends from every field of endeavor.

It was continually evident that he had at heart the best interests of the patient when the alternatives of surgical intervention were contemplated. As it should have been in any consideration of an injury or deformity, there was always in his mind the thought of the human being whom the lesion disabled, an appreciation of his personality, and an evaluation of his psychological needs in such times of duress.

He was strongly convinced of the importance of physical fitness. During his lecture on posture in one of the Instructional Courses presented by The American Academy of Orthopaedic Surgeons, he did not hesitate to strip down to exercise shorts and to demonstrate to his audience a series of exercises intended for regular use in the maintenance of good muscle tone and correct postural habits. In this respect, his excellence as a teacher was largely due to his insistence upon theory being delineated whenever possible by practical demonstrations. A meticulous regard for detail was yet another quality which impressed students through the years of his affiliation with the University.

Among his contributions to orthopaedic surgery was his endeavor to establish the value of manipulative therapy in the conservative treatment of internal derangements of the lumbosacral spine. He felt that such therapy should never be placed in any hands other than those of the properly qualified, and he stressed the limitations and complications as well as the advantages of its employment. His contributions to the literature cover a wide range of orthopaedic subjects, some of which reflected his great interest in the rehabilitation of the physically handicapped. During World War II, he was a member of the Baruch Committee on Physical Medicine.

Shortly after Pearl Harbor, he reported for active duty as a Naval Reserve Officer. His various assignments included that of Senior Medical Officer aboard the U.S.S. Mount Vernon (November 1942 to February 1944), a hospital ship which regularly evacuated casualties from the South Pacific islands to the California mainland; for the excellent discharge of his duties he received a letter of commendation from the Chief of Naval Operations. He was Chief of Orthopaedic Surgery at the United States Naval Hospital in St. Albans, Long Island, New York, and later at the United States Naval Hospital in Great Lakes, Illinois. Other assignments carried him to the Office of Rehabilitation, Bureau of Medicine and Surgery, Washington, D. C., and to the District Medical Office, Twelfth Naval District, San Francisco, California. It was in the latter city that he met and later married, in 1945, his gracious wife, the former Barbara Donohue of San Francisco.

After his return from war service, he was requested by the Dean's Committee to serve as Consultant in Orthopaedics to the Veterans Administration Hospital at Jefferson Barracks, Missouri. More recently, he had been president of the Missouri Society for Crippled Children and Adults, and Chairman of the Special Exhibit Committee on Fractures of the American Medical Association. He was a member of The American Academy of Orthopaedic Surgeons and of The American Orthopaedic Association. He was listed in *Who's Who in America*.

His death occurred on May 19, 1952.

It can surely be said that he always sought that which was best for orthopaedic surgery and for those needing its ministrations.

DALLAS BURTON PHEMISTER

1882–1951

On December 28, 1951, the medical world was saddened by the death of Dallas B. Phemister. He was universally recognized, by physicians and by laymen, as one of the great leaders of those who have devoted their lives to the betterment of mankind. Nothing can compensate us for such a loss, but we may do well to recall the achievement of Dr. Phemister and to reflect upon his influence which lives among us today and which will outlive us all.

Born on a farm near Carbondale in Southern Illinois, Dr. Phemister attended a country school and, after graduation from high school, continued his education at the Normal School of Northern Indiana. While there he decided to become a physician, and entered Rush Medical College of the University of Chicago, thus beginning an association with the University which was to be life-long. After graduation from Rush in 1904, he served an interneship at Cook County Hospital. He then entered private practice in LaGrange, Illinois, continuing at the same time his interest in teaching and research as a member of the Rush Faculty. In this period of American medicine, advanced training was available only abroad; so, after five years of practice, Dr. Phemister went to Vienna. Here began what became the most absorbing interest of his career, — the study

of the pathology of bone diseases. In 1911 he returned to Chicago to resume his teaching position at Rush, and established an association with Arthur Dean Bevan.

During World War I, Dr. Phemister served with the Presbyterian Hospital Unit, and at the end of the War returned to Rush Medical College, where he soon became Professor of Surgery. Although he carried on a large private practice, he devoted much time to teaching and laboratory research. Many of his contributions to the knowledge of bone and joint diseases, as well as to the field of general surgery, owe their inception to this period of his life.

With the organization of the new medical school at the University of Chicago in 1927, Dr. Phemister entered upon the most significant work of his career. The University asked him to undertake the task of organizing a department of surgery whose members were to devote all their time to teaching and investigation as well as to clinical work. Convinced that this concept of a full-time medical faculty was an important new principle, Dr. Phemister accepted the challenge. While awaiting the completion of the buildings of the University Clinics, he went to Europe for further study. In London he began his work on operative shock, a subject to which he made contributions of the greatest importance through the subsequent years.

With the opening of the University of Chicago School of Medicine, came the most productive years of Dr. Phemister's career. Not only did he make many contributions to knowledge, but, by his example, he stimulated others who came under his influence to do likewise. His research on bone tumors, infections, bone growth and repair, bone transplantation, and aseptic necrosis of bone radically altered the surgical care of patients with skeletal disorders. Although bone and joint diseases remained his primary interest throughout his life, other fields too were affected by his investigations. He was the first successfully to remove the oesophagus, in case of carcinoma, with re-establishment of continuity by anastamosis with the stomach. His studies on the formation and constituents of gallstones were fundamental. His early recognition of the need for blood replacement in surgical shock helped to revolutionize the surgical management of patients injured or convalescent from operation and made possible the greatly expanded surgical treatment which we know today.

Dr. Phemister's own accomplishments in the medical sciences would alone be sufficient to earn him a high place in medical history. He was most profoundly influential, however, as a teacher. His personal qualities of intellectual honesty, tireless energy, generosity, dignity, and simplicity deeply affected all who came in contact with him. He taught always by example, whether dealing with undergraduate students, residents, or staff doctors. His forthright honesty and constant striving for improvement in knowledge and methods stimulated generations of students. To the many scientific societies in which he took an active part, he brought the same high qualities.

Dr. Phemister's achievements won him every recognition of the medical world. He occupied positions of distinction in the surgical societies of the United States and in international associations. Many foreign societies conferred honorary memberships upon him. These honors he received with characteristic humility and always with a deep sense of obligation. His greatest personal satisfaction was to observe the growth and success of a student or an associate.

Sorrow at the loss of so great a colleague is tempered only by the realization that his scientific achievements, as well as the influence of his high personal qualities, will always be with us.

News Notes

The American Board of Orthopaedic Surgery announces that the deadline for the receipt of applications for the 1952 Part II examinations is August 15, 1952.

On June 13, the European orthopaedic surgeons paid tribute to Professor Jan Zahradníček, M.D., Chief of the Clinic of Orthopaedic and Pediatric Surgery at Charles University in Prague, on the occasion of his seventieth birthday.

Beloved as one of the great teachers of surgery throughout Central Europe, Professor Zahradníček began his career as a surgeon in the First World War. With the advent of the new Czechoslovakian Republic, he returned to Prague as assistant in the First Surgical Clinic where he worked in orthopaedic surgery with Professor Tobiasek.

In 1921 we find him Docent of Orthopaedic Surgery at Masaryk University School of Medicine at Brno. Later his teaching ability, ingenuity, skill, and initiative in surgical technique caused him to return to Prague in 1926, as Chief of the Third Surgical Clinic. After the death of Professor Tobiasek in 1931, he became Chief of the First Clinic of Orthopaedic and Pediatric Surgery of Charles University where he is still active.

His writings are numerous and far-reaching. His creative genius has led him to the development of outstanding techniques, particularly his corrections of deformities of the hip resulting from congenital dislocation.

Professor Zahradníček was the founder of the Czechoslovakian Society of Orthopaedic Surgery and Traumatology. He is a member of the International Society of Orthopaedic and Traumatic Surgery and of the French Surgical Academy; he is also an honorary member of the Polish and French Orthopaedic Associations.

He is devotedly loved by his many pupils, patients, and friends in Europe and America. All of his friends wish him many years of health and productive activity.

The Ohio Orthopaedic Society held its Annual Meeting in Akron, Ohio, on April 18 and 19, 1952, at the Akron City Club. The following program was presented:

Management of Recurrent Dislocation of the Shoulder: Dr. Harry O'Dell.
Case Presentations: Dr. James W. Parks.
Case Presentations: Dr. Patrick C. Doran.
Case Presentations: Dr. E. L. Voke.
Cervical Subluxation: Dr. Walter A. Hoyt, Jr.
Injuries with Massive Bone Loss: Dr. Fowler B. Roberts.
Tibialis-Anterior Transplant through Interosseous Membrane for Calcaneus Deformities: Dr. Fowler B. Roberts.
Treatment of the Resistant 5 to 10 per cent. of Club Feet: Dr. Fowler B. Roberts.
Cases of Coxa Vara. Treatment with Subtrochanteric Osteotomy: Dr. E. L. Mollin.
Os Calcis Fractures Managed by Conservative Treatment: Dr. Adrian E. Davis.
Use of Delayed Tibial Grafts in Non-Unions: Dr. Adrian E. Davis.
Cases of Charcot's Disease of the Knee Joint: Dr. Donald I. Minnig.
Complicated Fractures of the Distal Portion of the Femur and the Proximal Portion of the Tibia: Dr. Donald I. Minnig.
Cases of Proximal Row Carpectomies: Dr. Donald I. Minnig.
Eosinophilic Granuloma: Dr. George H. Bischoff.
Fibrous Dysplasia: Dr. Paul L. Weygandt.
Bilateral Fractures of the Clavicle: Dr. Paul L. Weygandt.
Treatment Problems in Multiple Traumata: Dr. Walter Brown, Jr.

The first national meeting of the **Sociedad Cubana de Ortopedia y Traumatología** was held in Havana on February 7, 8, and 9, 1952. Dr. Pedro Sánchez Toledo opened the meeting, held at the *Hospital Militar*, with a review of the development of orthopaedic and traumatic surgery in Cuba. Credit for the development of the specialty in the first decade of the century was given to Enrique M. Porto who studied under Sayre and Whitman and to Armando Guerraro (a general surgeon). Alberto Inclán followed Porto and later became the first Professor of Orthopaedic Surgery at the University. In 1933, Inclán founded *Cirugía de Ortopedia y Traumatología;* in 1944, under the presidency of Inclán, the *Sociedad Cubana de Ortopedia y Traumatología* was formed. From a small group of orthopaedic surgeons in Havana, the society has grown to include forty-eight active members who maintain clinical services in every hospital in Havana and in most of the hospitals in the capitals of the provinces.

The objective of this first meeting was to bring together all Cuban orthopaedic surgeons in the interests of scientific progress and to establish bonds of fraternal and scientific exchange with all the countries of the Americas; there were more than 200 in attendance. Dr. J. Luis Bado of Montevideo, Uruguay, and Dr. Carl E. Badgley of Michigan, the United States of America, were guests of honor.

The meeting of the first day was held at the *Hospital Militar*. After the opening speech by Dr. Pedro Sánchez Toledo, the assembly saw, by means of television, Dr. Badgley perform two operations,—one for fusion of a scoliotic spine, supplemented by the Risser technique, and the other for an ununited fracture of the tibia.

During the afternoon session of the meeting of February 7, a symposium on displaced fractures in the adult was presented by Dr. Luis Iglesias de la Torre, director of the *Hospital Militar*, and his staff. Dr. Iglesias presented a review of the general principles underlying treatment. An excellent selection of methods of therapy was demonstrated, presenting not only a conservative choice of treatment but, where required, a bold selection of therapy based on the most modern of concepts.

A statistical review of diaphyseal fractures of the femur, forearm, humerus, and tibia was then presented by men on his Service. Excellent results were achieved with the various forms of treatment chosen for individual cases.

The meetings on February 8 and 9 were held at the *Hospital Mercedes*. There, on the morning of February 8, Dr. J. Luis Bado demonstrated, by means of television, his procedure (a combined Brittain-Trumble method) for fusion of the tuberculous hip joint.

In the afternoon, Dr. Pedro Sánchez Toledo and his colleagues from the *Hospital Municipal de Infancia de La Habana* presented a symposium on fractures of the forearm in infants. Over 6,075 cases have been collected since 1935, and 1675 patients have been treated surgically. Fifty Monteggia fractures and three cases of ischaemia were recorded.

That evening, at the *Academia de Ciencias*, a formal meeting was held. Dr. J. Luis Bado, who was introduced by Dr. Inclán, presented a paper on the Physiopathology and Classification of Flat Feet. He was then made an honorary member of *La Sociedad Cubana de Ortopedia y Traumatología*. Dr. Luis Iglesias introduced Dr. Carl E. Badgley who gave an address entitled "Technical Operative Procedures for Special Types of Non-Union of Fractures of the Lower Extremity". He was also made an honorary member of *La Sociedad Cubana de Ortopedia y Traumatología*.

During the morning session of February 9, Dr. José Ignacio Tarafa gave a talk devoted to *El Centro de Rehabilitación de Lisiados "Franklin D. Roosevelt"*.

The meeting officially closed with luncheon. Dr. Luis Iglesias de la Torre was elected to succeed Dr. Inclán as president and Dr. Raúl Rodriguez Gutiérrez was chosen to be secretary.

SOCIEDAD ARGENTINA DE ORTOPÉDIA Y TRAUMATOLOGÍA

The Second National Congress of the Society (*Segundas Jornadas Argentinas de Ortopédia y Traumatología*) was held in Córdoba, Argentina, on December 6, 7, and 8, 1951, under the presidency of Dr. Luis A. Weber and Dr. Carlos E. de Anquin, the latter the President of the local Society.

Over 100 delegates attended this important meeting. Three symposia, on arthrodesis of the spine, on flat-foot, and on fractures of the knee joint (excluding the patella), were presented, as well as a number of important short communications.

Arthrodesis of the spine was discussed, and methods and end results were shown. Methods of use of massive bone grafts and bone chips were compared; careful technique was emphasized as well as the advantages of the bone bank and the necessity for prolonged immobilization.

The following papers were read:

Arthrodesis for Spondylolysis and Spondylolisthesis: Carlos E. de Anquin.

A Few Considerations on Lumbosacral Anthrodesis: José M. del Sel.

Arthrodesis of the Lumbosacral Region: Oscar R. Marottoli.

Low-Back Pain due to Horizontal Sacrum: Valentin Girardi and C. Defilippis Novoa.

Arthrodesis of the Spine by means of Albee's Technique: Sara Satanowsky.

End Results of Arthrodesis of the Spine: F. Segura and M. Freytas.

Follow-up Study of Arthrodesis of the Spine: L. J. Petracchi and C. L. Aiello.

Arthrodesis of the Spine for Tuberculous Spondylitis in Children: A. Fagalde.

Arthrodesis of the Spine for Low-Back Pain; an End-Result Study: R. Ferré, E. Comolli, M. Azar, L. Uslenghi, and G. Aranovich.

Functional Difficulties after Lumbosacral Arthrodesis: H. Dal Lago and A. Vera.

End-Result Study of Arthrodesis of the Spine: J. Trujillo, I. Ayerza, and A. Mejía.

Observations on Scoliosis: C. Khoury.

A Study of Arthrodesis of the Spine: J. Zarazaga.

Surgical Indications for Low-Back Pain and Sciatica: F. Segura and T. Mosquera.

Arthrodesis of the Spine for Scoliosis: R. Ferré and E. Comolli.

A Technique for Lumbosacral Arthrodesis: L. L. Fernandez.

In discussing flat-foot, there was general agreement that further studies have to be undertaken. The following papers were read:

The Treatment of Flat-Foot: O. Natiello.
The Treatment of Foot Troubles in Connection with Flat-Foot: O. Natiello.
Anatomical and Clinical Studies of Flat-Foot: José M. del Sel.
The Technique for Arthrodesis of Intractable Flat-Foot: José M. del Sel.
Valgus Flat-Foot: R. J. Caritat (Uruguay).
Flat-Foot: R. Ferré, E. Comolli, L. Uslenghi, and R. Rositano.
The Treatment of Flat-Foot: H. Dal Lago and A. R. Vera.
Surgical Treatment of Flat-Foot: F. Oleaga Alarcón.
Surgical Treatment of Adolescent Flat-Foot: V. Girardi, A. Plaghos, and I. Kuras.
Conservative Treatment of Flat-Foot: D. Ortiz.
Observations on Flat-Foot in Infancy: J. Zarazaga.

In the discussions on fractures of the knee joint (excluding the patella) there were two opposite schools of thought presented: non-operative and operative treatment. Agreement again came after it was pointed out that the experienced surgeon has to decide which is the best solution in each case.

The following papers devoted to the subject were read:

Treatment of Fractures of the Tibial Tuberosities: I. Castillo Odena and O. Natiello.
A Study of the Treatment of Fractures of the Tibial Plateau: V. Girardi and A. Plaghos.
Fractures of the Tibial Tuberosities: J. Sgrosso and T. Gismondi.
Fractures of the Femoral Condyles: A. Didier.
Treatment of Fractures of the Tibial Tuberosities: D. Múscolo and E. Pacios.
Fractures of the Lower End of the Femur: R. Ferré, E. Comolli, L. Uslenghi, and M. Azar.
Fractures of the Lateral Tibial Plateau: R. Ferré, E. Comolli, L. Uslenghi, and H. Esteban.
Fractures of the Tibial Plateau: F. Arena and J. Bogliano.
Fractures of the Knee Joint: L. G. Lezama.
Some Observations on Fractures of the Tibial Plateau: D. Vazquez Rolfi (Uruguay).

The following short communications, although unrelated to the subjects of the symposia, were also presented:

Fractures of the Patella; Patellectomy; End Results: D. Vazquez Rolfi (Uruguay).
Arthrosis in Old Meniscectomies: J. Lorenzo and A. Mussio (Uruguay).
Phlebographic Studies in Fractures of the Lower Limb: C. E. Ottolenghi and H. Manfredi.
Phalanx and Metacarpal Bone Bank; Practical Advantages of Homotransplants of Small and Large Bones: P. V. Pedemonte (Uruguay).
Filling with Cancellous Bone in Chronic Osteomyelitis and Bone Tuberculosis: C. Urrutia and S. Narvaez (Chile).
Osteo-Articular Brucellosis, Excluding Spondylitis: Carlos E. de Anquin.
Brucellosis of the Spine: Carlos E. de Anquin.
Alternate Fracture-Dislocation of the Forearm: I. Castillo Odena.
Fractures of the Jaw: C. Garcia Novales (Uruguay).
Pigmented Villonodular Synovitis: I. Slullitel and J. Slullitel.
The Approach to the Upper End of the Radius: T. Gismondi and R. Vives.
Arthrosis of the Shoulder Joint: R. J. Caritat (Uruguay).
On Arthrosis: R. J. Caritat (Uruguay).
Some Considerations of the Treatment of Congenital Club-Foot: A. Fernandez Vocos.
Tuberculous Tenosynovitis of the Wrist: C. L. Aiello.
Treatment of Fractures of the Shaft of the Tibia by Bipolar Anchorage: H. Varalla and A. Costa Paz.
Reconstruction of Severed Flexor Tendons of the Fingers: P. V. Pedemonte (Uruguay).
Bado's Sign of Torn Semilunar Cartilage: J. Lorenzo and A. Mussio (Uruguay).
Arthrodesis of the Knee Joint: J. L. Bado and J. Garcia Novales (Uruguay).
Arthroplasty of the Elbow with Interposition of Skin: F. Segura, J. Dalla Villa, H. Martinez, and T. Mosquera.
Transacromial Approach to the Shoulder Joint: Carlos E. de Anquin.
Damage to the Pelvic Joints During Pregnancy and Parturition: G. Allende and L. G. Lezama.
Radiology in Congenital Club-Foot: L. G. Lezama.
Giant-Cell Tumor of the Femur with Multiple Metastases of Identical Histological Type: C. E. Ottolenghi, F. Schajowicz, and S. Mondolfo.
Ischio-Femoral Arthrodesis: L. J. Bado and J. Garcia Novales (Uruguay).
Surgical Treatment of Fractures of the Shaft of the Femur through a Window in the Cast: A. Carrion.
Mixed Arthrodesis of the Hip Joint: C. Urrutia (Chile).
Décalage of the Lower End of the Ulna: A. A. Salvati.

Book Reviews

FRACTURES AND JOINT INJURIES, Vol. I, Ed. 4. Sir Reginald Watson-Jones, B.Sc., M. Ch. Orth., F.R.C.S., F.R.A.C.S.(Hon.), F.A.C.S.(Hon.). Edinburgh, E. & S. Livingstone Ltd., 6 pounds per set; Baltimore, The Williams & Wilkins Company, 1952. $22.00 per set (not sold separately).

How Sir Reginald finds time to do one-tenth of his work is difficult to understand. He does, however; and with responsibilities which would wear down a corps of average surgeons, he has now produced the Fourth Edition of his classical text and reference book on fractures and joint injuries. This review is concerned only with Volume I.

As he points out in the Preface to this Edition, "every page has been corrected or rewritten, new chapters have been added, and several hundred new illustrations have been prepared. There are new chapters on wound-shock and the adaptation syndrome in its relation to shock; on the treatment of open fractures and joint wounds, chemotherapeutic control of infection, early closure of wounds by secondary suture or skin grafting, and plastic surgery in fracture treatment; on transplantation of bone, cancellous bone grafting and intramedullary nailing with a series of case reports of typical bone-grafting operations; and on fatigue fractures and pathological fractures, with a review of bone disease that covers almost the whole of orthopaedic surgery."

This reviewer has never seen better teaching than is represented in this volume and has almost never seen teaching that approaches it in clarity, force, enthusiasm, and the ability to inspire. Work of this sort is a contribution of incalculable value to the welfare of mankind. Without the volume it would hardly be possible to deal adequately from any surgical standpoint with the subjects of which it treats. The edition will take its place in every representative orthopaedic library throughout the world.

THE ORGANIZATION OF BONES. P. Lacroix. (Translated from *L'Organisation des Os*, Paris, the Amended French Edition, by Stewart Gilder, Masson et Cie, 1949.) Philadelphia, The Blakiston Company, 1951. $6.00.

This book is a stimulating account of the studies by an eminent scientist and teacher of the phenomena of the development, structure, and behavior of bone. In no sense a textbook or brief compilation of the accredited knowledge in these fields, it is rather an essay on the dynamics of skeletal development based on articles published by the author on his investigations of this subject and on the published works of others. While the histological approach to the problems discussed predominates, important biochemical and embryological aspects are duly considered.

The author's views rest in part on his histological studies of growing bone and in part on results observed in periosteal, osseous, and medullary grafts planted under the renal capsule. They are of special interest and are stimulating in their suggestions in relation to the local chemical factors concerned in the growth, maintenance, and repair sequences in bone.

The material has been excellently presented; the illustrations, mostly photomicrographs and occasionally schematic drawings, are of good quality.

This little book is not only of great interest to all students in any way concerned with the biology of bone, but it has a useful part to play in the world of orthopaedic surgery, for it succeeds admirably in focusing attention not only on one of the fundamentals of the specialty—a knowledge of the development, structure, and behavior of bone—but also indicates that there is still much to be learned in this field.

RUPTURES OF THE ROTATOR CUFF. H. F. Moseley, M.A., M.Ch.(Oxon.), F.R.C.S. (Eng. and Canada). Springfield, Illinois, Charles C. Thomas, 1952. $6.50.

This ninety-page monograph contains a presentation of the anatomy, function, rupture, and operative repair of the shoulder-cuff tendons. The section on static anatomy is clear and accurate, and it includes a fresh concept of the shoulder mechanism as viewed through the axilla. The description of cuff function is oversimplified, however, and is less clear and complete. The clinical picture of cuff rupture at various stages after injury is discussed in detail, but the problem of differential diagnosis receives little attention. The author offers two contrasting alternatives for conservative therapy, rest in abduction or a sling and early exercises, but he leaves the reader in doubt as to which he advocates or employs. Early operative repair is advocated for all lesions, despite acceptance of a 25 per cent. incidence of cuff ruptures in cadaver studies. The pathological patterns of cuff tears and the operative technique for their repair are well described and beautifully illustrated, and the author's program of after-care is outlined. The last twenty pages are devoted to case reports documenting the author's experiences. This section is interesting but of questionable importance, and leaves the reader with the thought that the space might better have been used to enlarge upon some of the unique and often controversial material in the earlier portion of the text.

This didactic book is well written, dogmatic, and clearly expresses the author's thoughts on his subject. It is not complete, but it should be read by all surgeons interested in the shoulder, not only for the information contained, but also for the visual concept provided by many superb colored illustrations which in the opinion of this reviewer mark a milestone in medical literature.

A Textbook of Orthopaedics with a Section on Neurology in Orthopaedics. M. Beckett Howorth, M.D. Philadelphia, W. B. Saunders Company, 1952. $16.00.

Textbooks of orthopaedics are not numerous and the appearance of a new one is an interesting and an important event. As stated by the author, "the purpose of this book is to provide the basic facts of the etiology, pathology, diagnosis, and treatment of abnormalities and diseases of the musculo-skeletal system for the physician interested in these problems". In this major undertaking, the author has been assisted by several co-authors.

The book is large—over 1,000 text pages. It is well printed and the illustrations are particularly worthy of praise. They are numerous, well chosen, and of excellent clarity. The book is divided into four sections: (1) Introduction and Basic Principles of Orthopaedic Practice, (2) Regional Orthopaedics, (3) Orthopaedic Disorders, and (4) Neurology in Relation to Orthopaedic Practice.

The author has attempted to make this book all-inclusive. A short history of the development of orthopaedics as a specialty, a review of the anatomy and physiology of the musculoskeletal system, amputations, and fractures are covered, in addition to the usual subjects found in an orthopaedic text. There is also a large section on neurology.

Obviously, in attempting to cover so much ground, many of the subjects are treated briefly and in general terms. There is a well selected list of references at the end of each chapter which gives the interested physician a key to the pertinent literature.

This reviewer fears that the medical student will find the book heavy in his hands and on his purse. The prose style is pedestrian and a little pedantic. Few will gain pleasure from reading this book, but the amount of information it contains is enormous; it can be consulted by student, physician, or surgeon with profit.

Calculation of Industrial Disabilities of the Extremities. Carl O. Rice, M.D. Springfield, Illinois, Charles C. Thomas Co., 1952. $10.50.

Perhaps no topic in the field of orthopaedics deserves standardization as much or lends itself to standard measurements as little as does the subject of this textbook. The author has simplified the problem very greatly by limiting his discussion to calculations of the degree of anatomical loss and the impairment of functional use in the injured member. He feels that the cash value of this loss must be estimated, not by the doctor, but by the Industrial Board making the award. The author, therefore, stresses didactic calculations which lead to exact conclusions.

With the aid of numerous excellent illustrations, various methods of measurements are presented, showing ranges of motion in the different joints. Percentages of disabilities are worked out by mathematical equations, after measuring the loss of motion to individual joints or "members"; and further calculations are offered for combined injuries of several joints. Very useful reference charts are included showing arbitrary values of disabilities as assessed in each of the states.

The chief drawback to this study lies in its completely mechanical approach to the question. For instance, there is no section in which is discussed the amount of disability resulting from traumatic arthritis or bursitis in which loss of function is based on the degree of pain rather than on the degree of movement. The importance of pain is here regarded as "too intangible to be much more than a good guess"; and the author, therefore, discounts it altogether. Muscle weakness is also omitted from the factors used in the author's calculations, except when great enough to be put down as total. Incoordination and tactile sensation are also deliberately overlooked; and there is no discussion of instability of joints, such as a knee with ruptured ligaments, or a chronic sprained ankle.

A more far-reaching study of industrial disabilities would include the relationship of the type of job to the type of disability, and would interpret its findings in the light of individual and personal factors. The author discusses many aspects of disability evaluation in an excellent chapter on historical considerations. Here he presents summaries of the theories and methods of leading authorities. A succinct condensation of Magnuson's views on the subject is one of the most worth-while commentaries in the entire book. Brief analyses of the systems of Kessler and of McBride give an insight into their important contributions. All in all, this text offers so much good material and presents it so well that it will be of real value as a reference work.

The Management of Fractures, Dislocations, and Sprains, Ed. 5. John Albert Key, B.S., M.D., and H. Earle Conwell, M.D., F.A.C.S. St. Louis, The C. V. Mosby Company, 1951. $16.00.

Those familiar with the field of traumatic and orthopaedic surgery will need no introduction to this

excellent work. The last edition was published in 1946. The volume under review represents an extensive revision; many of the old illustrations have been omitted and much new material has been added.

Among the most important additions is the discussion of medullary nailing in fractures of the femur and of the tibia, with special reference to indications, the technique of nailing, determination of the proper size of the nail, and the method of insertion.

Two chapters from the previous edition, on "The Workman's Compensation Law Affecting Fracture Cases" and on "Medicolegal Aspects of Fracture Cases", have been omitted; in view of the increasing specialization in these fields, it was perhaps wise to restrict the present text to the strictly medical and surgical aspects of fractures.

As in earlier editions there is a chapter on "Fractures of the Skull and Brain Trauma" by Edgar F. Fincher and a chapter on "Fractures of the Jaws and Related Bones of the Face" by James Barrett Brown.

The new edition of this invaluable work will be welcomed by students, general practitioners, and surgeons alike.

AN ATLAS OF NORMAL RADIOGRAPHIC ANATOMY. Isadore Meschan, M.A., M.D., with the assistance of R. M. F. Farrer-Meschan, M.B., B.S. (Melbourne). Philadelphia, W. B. Saunders Company, 1951. $15.00.

It is the purpose of the authors of *An Atlas of Normal Radiographic Anatomy* to present in a handy, standard-sized volume the necessary background in roentgenology needed today by students and practitioners alike. The authors deal with normal anatomy as shown by roentgenograms, for only after it has been mastered and has been correlated with the reader's knowledge of the gross anatomy of the body can the pathological as viewed on roentgenograms be recognized and have significance.

The Atlas begins with a brief introductory chapter devoted to the physics of x-rays, steps in the production of a roentgenogram, and a description of the accessories needed to produce various types of roentgenographic images. Then follows a long section of several chapters concerned with the roentgenographic anatomy of the skeletal system.

In this section, as indeed in the other sections, such as those devoted to the brain, heart, and gastrointestinal system, the authors give the basic morbid anatomy as it concerns roentgenography, the manner in which routine views are obtained, a concept of the various anatomical parts best seen in the routine views, and the common variations from the normal. In addition to this, the latest advances in such techniques as myelography and angiocardiography, to name but two, are presented.

The method of illustration is highly original and instructive and yet quite simple. First is given an artist's line drawing of the patient placed in the proper position for the taking of a routine view, with that portion of the patient's body under consideration clearly marked. The position of the cone is always distinctly shown in each of these drawings. Then is shown a reproduction of the resulting roentgenogram; beside it, or on the facing page, is a well-labeled tracing of the roentgenogram, in which the anatomical parts shown in the roentgenogram are pointed out. The legends for these figures are concerned with points of interest in the posing of the patient, the adjusting of the roentgenographic equipment, and hints upon how the best result is to be obtained.

The authors and the publishers are to be congratulated upon a splendid piece of work.

CONGENITAL DISLOCATION OF THE HIP. Julius Hass, M.D. Springfield, Illinois, Charles C. Thomas, 1951. $12.50.

This book is an excellent and a complete review of all the literature on congenital dislocation of the hip; it is supplemented by material derived from a large European clinic. Such a thorough study of the subject serves to re-emphasize the fact that we have achieved no unanimity of opinion as regards the etiology, the pathogenesis, or even the treatment of this condition.

Any student of the problem of congenital dislocation of the hip may find some points of disagreement in the author's statements. The author advocates without question the position of flexion and abduction (frog position) for postoperative fixation, and frowns on the position of extension, abduction, and internal rotation. He fails to state that, when preliminary skeletal traction has been employed and when relaxation of the soft tissues is sufficient to determine the position of maximum stability, one will often find the position of extension, abduction, and internal rotation to be the more secure. The author believes that correction of anteversion of the femoral neck is seldom indicated; yet he states that it may be an important factor in recurrent dislocation of the hip. Here again he fails to emphasize adequately that surgical correction of this associated deformity should be considered when reduction in a position of internal rotation affords a more stable hip.

In his discussion of secondary changes which occur in the femoral head, he minimizes the possible effect of trauma and increased intra-articular pressure on the production of these changes which can be classified under the term aseptic necrosis. He discredits statements in the literature that the possibility of secondary aseptic necrosis can be eliminated by the use of preliminary skeletal traction. The author, however, has had no experience with this form of therapy.

This work will be of value for reference. It gives the reader of the English-language literature access to the foreign literature in a clear and concise manner. The bibliography leaves nothing to be desired.

In spite of the very obvious differences of opinion regarding conclusions reached by some clinicians in this country, the discussion and consideration of the over-all problem of congenital dislocation of the hip is excellent and is well presented.

SURGICAL TREATMENT OF THE MOTOR-SKELETAL SYSTEM, Ed. 2. Frederic W. Bancroft, A.B., M.D., F.A.C.S., and Henry C. Marble, A.B., M.D., F.A.C.S. Philadelphia, J. B. Lippincott, 1951. $24.00.

This new edition, six years after the publication of the original, follows the pattern of the first edition and certainly measures up to the standards previously set. The material has been divided into fourteen sections; forty-four separate articles have been prepared by forty-eight authors. All phases of orthopaedic surgery have been covered with perhaps more emphasis on operative treatment than on non-operative treatment, as the title might imply.

In a publication of this kind, the comment that there is lack of uniformity of excellence of articles is nearly always made; this is a valid criticism of this text. Some of the sections are excellent, some are good, and some are only fair; some are too long and some are much too short for the subjects covered; some have not been revised sufficiently; and some are poorly illustrated, but, on the other hand, many have beautiful illustrations.

The contents and arrangement of the book are essentially the same as in the first edition. The late Dr. C. R. Murray's section on "General Discussions of Fractures, Dislocations, and Other Trauma" is excellent and one of the best; however, if Dr. Murray had revised this section, he would not have emphasized the types of external skeletal-fixation apparatus which are given considerable importance in the illustrations and which are now seldom used. The other sections originally prepared by Dr. Murray on "Affections of Muscles, Fasciae and Tendons", "Tumors of Muscles, Fasciae and Tendons", and "Miscellaneous Bone Disease and Infection" have not been well revised. The second of these sections would have been better included in Coley's section on "Tumors" which is excellent.

The section on "The Surgical Treatment of Scoliosis" by von Lackum, "Joint Infections and Arthritis" by Key, "The Physiology of Bone Repair" by Urist, "Internal Derangements of the Knee" by Stinchfield and Cavallaro, "Fractures of the Ankle and Foot" by Hermann, and "Fractures and Dislocations of the Carpus" by D. W. G. Murray are particularly outstanding and worthy of mention.

Some of the illustrations of the book are poor, particularly the reproductions of many of the roentgenograms. This is unfortunate as it detracts much from the articles. This is noticeably true in the sections on "Congenital Deformities of the Lower Extremities" by Kite, "Surgical Treatment of Scoliosis" by von Lackum, "Tumors of Bones and Joints" by Coley, and "Fractures and Dislocations Involving the Elbow Joint" by F. M. Smith. Also many of the photographs in Kite's section are poor, as well as some of the photographs in Cleveland's section on "Anterior Poliomyelitis". The four sections on "Congenital Deformities" would have been more uniform and better if they had been prepared by one author, such as Kite, who has given probably as much thought to this subject as any orthopaedist in the country today.

In some instances it appears to the reviewer that the book would have been improved with a rearrangement of authors. For example, Ober and Dickson are known for their work on anterior poliomyelitis, but yet Cleveland, who is known for his work on tuberculosis of bones and joints, has written the section on poliomyelitis and Ober has written part of the section on "Congenital Deformities" and Dickson "Tuberculosis of Bones and Joints". McLaughlin, who has long been known and recognized as an authority on the shoulder, has not written on it here but has prepared the section on "Injuries to Ribs, Costal Cartilages, Sternum and Sternoclavicular Joint". These are only a few of the examples of author assignments which are puzzling to the reader.

The section by Phelps on "Treatment of Paralytic Disorders Exclusive of Poliomyelitis" is incomplete. "Hip Fractures" by Thornton is much too short for a subject as important as this. The section on "Fractures of the Shaft of the Femur" by Impink and Lee, although well written, is lacking in a good description of intramedullary nailing which is becoming firmly established as an accepted form of treatment in selected cases. The discussion of "Compound Fractures" by Darrach and Stimson would have been better combined with the same discussion by C. R. Murray, which is excellently done.

In McCaffrey's really good discussion on "Fractures of the Jaw", no mention is made of the external skeletal-fixation methods which were so firmly established as good procedures during World War II.

From the point of view of the orthopaedic surgeon, the greatest weakness of this second edition is that neither the supervising editor nor the associate editor is an orthopaedic surgeon, which is not true for the first edition. In spite of the eminence of the two editors in their field of general surgery, including the surgery of trauma, it is the opinion of the reviewer that, in a publication in which 60 per cent. of the authors are Board-certified orthopaedic surgeons and at least 90 per cent. of the articles involve conditions primarily treated by orthopaedic surgeons, and which has been and will continue to be considered by everyone a textbook of orthopaedic surgery, the publishers have made a serious error in not having as one of the editors an orthopaedic surgeon.

The book contains a wealth of information and is to be recommended for the orthopaedic sections of all libraries. It will continue to be a useful reference book for the orthopaedic surgeon. In two volumes of over 1,300 pages with forty-eight authors, it could not be expected, of course, to have all sections equally good. It is hoped that the few criticisms of the reviewer may be helpful to the publishers in preparing another edition which, it is sincerely hoped, will have an orthopaedic surgeon as one of the editors.

A Textbook of Clinical Neurology, Ed. 7. Israel S. Wechsler, M.D. Philadelphia, W. B. Saunders Co., 1952. $9.50.

In the five years since the appearance of the last edition, the book has been revised and modernized in a number of respects. Certain sections have been omitted and its length has been reduced by twenty-eight pages. The illustrations have been improved, and the paper used is more attractive.

The book, however, remains essentially unchanged in character. Informative, but frequently inaccurate, with irregularities in scope, the volume is not fully dependable. Reference citations and drug dosages are not given in a uniform manner.

In spite of its good features, the book cannot, even in its twenty-fifth year, be unequivocally recommended.

Roentgenologic Diagnosis of Diseases of Bone. David G. Pugh, M.D. Thomas Nelson and Sons, New York, 1951. $5.00.

This book is reprinted from Nelson's Loose-Leaf *Diagnostic Roentgenology* and presents the fundamental points in the roentgenographic diagnosis of bone diseases. The author states in the introduction that "a student of roentgenology should not attempt to remember all of the varied roentgenographic appearances of the various diseases but should become acquainted with the various pathologic changes which take place". He has presented these points with excellent summaries of the physiology and histology, and of the development of the skeleton. This section is followed by clear and concise descriptions of the more common processes and lesions which may be encountered. The book is well illustrated and its format is satisfactory. It is unreservedly recommended, particularly to those interested in bone diseases and their roentgenographic appearance.

La Pratique des Déviations Vertébrales. Scoliose — Cyphose — Lordose. C. Roederer and R. Ledent. Paris, G. Doin & Cie, 1951. 1.700 fr.

According to the authors, this book is written for the practitioner. However, it is easy to see at once that the practitioner is probably not the orthopaedic surgeon, because the greater part of the book is dedicated to the treatment of scoliosis by physical therapy, physical education, and corrective exercises. Only a single chapter of about five pages is given to a review of surgical treatment.

Despite the scant mention of orthopaedic surgical treatment of scoliosis, the book presents a certain value to the orthopaedic surgeon in bringing out fundamental facts in the examination and analysis of a patient with scoliosis. There are many interesting statements throughout the book. One cannot disagree with the statement of the authors that the treatment of a confirmed scoliosis is a perpetual and disagreeable lesson in humility.

The book is divided into several parts. In the preliminary section there is a satisfactory review of the elementary fundamentals of anatomy, development, and roentgenography. This section also includes a description of the pathological curvatures and general evolution of scoliosis. There is a good chapter on examination.

The second section includes the treatment of scoliosis by various physical means, including the plaster-of-Paris application.

The third section describes the treatment of the round back and kyphosis, and the last section is dedicated to the treatment of lordosis.

Although the general impression on perusing the book is that it belongs to the first decade of the twentieth century with line drawings and illustrations which were popular in the books of that period, the numerous aphorisms and useful new facts and points of keen observation make this book interesting reading for the orthopaedic surgeon and useful reading for the physiotherapist who can read French.

Post-Graduate Lectures on Orthopedic Diagnosis and Indications, Vol. III. Arthur Steindler, M.D., F.A.C.S. Springfield, Illinois, Charles C. Thomas, 1952. $8.75.

This is the third volume in a four-volume series of postgraduate lectures by the master clinician and teacher, Arthur Steindler.

In this volume the author achieves the same high standard of excellence established in Volumes I and II. Two subjects are presented in two sections: Section A, Tuberculosis of the Skeletal System, and Section B, Osteomyelitis.

Section A. *Tuberculosis of the Skeletal System:* A comprehensive dissertation on this subject is presented, not merely a discussion of symptoms and treatment. A detailed description of the pathological anatomy, pathogenesis, and laboratory diagnosis introduces the subject. The discussion of clinical diagnosis and thera-

peutic management have their foundation solidly anchored in a profound knowledge of the disease, acquired in a long career dedicated to the advancement of orthopaedic surgery. Newer concepts of therapy, including streptomycin, are thoroughly discussed. After a general discussion of tuberculosis of the skeletal system, there follows a detailed description of the disease in the various localizations, in particular the spine, hip, knee, ankle, shoulder, elbow, and wrist. Controversial aspects of the subject, such as the place and timing of arthrodesing procedures, are skillfully presented.

Section B. *Osteomyelitis:* In this section osteomyelitis is discussed in the same thorough manner as was skeletal tuberculosis. Diagnosis and therapy are discussed in the light of the pathological anatomy. The details of antibiotic therapy are well described. Little-known facts about the subject, particularly as related to rare locations, will be appreciated by students of this subject. Also included are descriptions of rare forms of osteomyelitis associated with such diseases as typhoid fever, malta fever, salmonella, smallpox, mycotic infections, and echinococcosis.

It is indeed fortunate that Dr. Steindler has found the time and energy to make this great series of lectures available to the profession. Mr. Charles C. Thomas, the publisher, has given the book fine physical qualities. All physicians whose work deals with the musculoskeletal system should have these volumes of Post-Graduate Lectures within easy reach.

Atlas der Pathologischen Anatomie. Eine Sammlung Typischer Krankheitsbilder der Menschlichen Organe. Dr. Robert Rössle und Dr. Kurt Apitz. Stuttgart, Georg Thieme Verlag, 1951. DM 87.

In this excellent volume the illustrations outweigh the text. Written primarily for beginners and for residents with little experience in autopsies, the text is confined chiefly to general pathological subjects. Few rarities will be found here; instead, the broad relationships among the various pathological conditions illustrated are stressed, and specific conditions are dealt with in terms of the general pathological categories in which they belong.

Readers of this *Journal* will be especially interested in the brief, concise discussion of bone marrow and its changes in various diseases of bone, and in the excellent illustrations of the pathology of bones and joints.

The preface gives a brief history of this volume. Dr. Apitz is listed as co-author, although he died in 1945, the year for which publication had been planned. Parts of the book which had been set in type during the war were destroyed in air attacks. Dr. Rössle and the publishers are to be congratulated for carrying on this work in spite of the many difficulties they encountered.

Traumatologia de los Meniscos de la Rodilla. J. R. Cabot. Madrid, Editorial Paz Montalvo, 1951. 165 Ptas.

This volume, which is dedicated to Dr. Emilio Moragas Ramirez, summarizes our knowledge of injuries to the meniscus and reviews the author's experience with 1,230 patients, in 730 of whom operations were done.

After a review of the earliest descriptions of lesions of the meniscus, the anatomical relationships and physiology of the meniscus are given. It provides uniform lubrication to the articular surfaces, protects the joint at the extremes of motion, and stabilizes movement at the knee. The meniscus moves by reason of the lax parameniscal zone. Injuries to the meniscus are observed chiefly in men in active life. Obesity, poorly developed muscles, genu valgum, and adhesions predispose to injury.

Ruptures of the meniscus are traumatic, although there may be disease or degeneration in the meniscus. There may be a single violent trauma or repeated small injuries; tears occur with brusque movements and poor coordination. Many mechanisms of injury are described, but internal rotation with abduction is the most common. What occurs is actually an increase in the diameter of the meniscus. Most ruptures are longitudinal and begin in the posterior segment, followed by anterior displacement. In each instance, in addition to the anatomical lesion, there are functional, vasomotor, and synovial changes. After a month, fibrosis occurs about the lesion. True ruptures do not heal; only peripheral lesions in which there is a good blood supply show complete repair.

Lesions of the meniscus may be divided into longitudinal rupture, transverse rupture, peduncular rupture, regenerative changes, degenerative changes, and congenital anomalies. Degenerative changes are seen after the age of thirty; later calcification may be seen subsequent to traumatic or degenerative changes. Most repair is false, fibrinoid. Symptoms may be local, general, or both. Locking was found in 30 per cent. of the cases.

Diagnosis can often be made from the history and physical examination, but at times these may be deficient. Stress is placed on persistent limitations of extension as well as upon pain on rotation of the knee. Among the complementary procedures, arthro-endoscopy is sometimes of value. The author finds pneumoarthrography helpful and feels that it is indicated when there is unexplained locking or articular laxity.

Roentgenograms are made with the patient prone and the knee in abduction. Plain roentgenograms are of value chiefly in ruling out the possibility of other lesions. When there is blood in the synovial fluid, a meniscal rupture may be suspected.

Therapy varies: if there is a definite rupture, operation is indicated; in the milder and indefinite lesions, novocain infiltration and roentgen-ray therapy are sometimes of value. The author reports suture of the rupture, but he states that this is only of historical interest, since repair occurs only in the vascularized peripheral zone. Meniscectomy should be complete with a minimum of operative trauma and with protection of the supporting tissues. There should always be re-establishment of the synovial continuity and an early resumption of activity. The parapatellar incision is adequate in most cases. A compression bandage is used postoperatively.

Functional re-education includes resistance exercises. In the series reported, the patients were hospitalized on an average of eight days, with subsequent ambulatory treatment for thirty days.

MEDIZINISCHE RÖNTGENTECHNIK. Lehrbuch für medizinisch-technische Assistentinnen, Studierende und Ärzte. I: Medizinischer Teil (Skelettaufnahmen und Organuntersuchungen). Prof. Dr. Herbert Schoen. Stuttgart, Georg Thieme Verlag, 1951. DM 22.50.

Schoen, one of Germany's best known roentgenologists and for many years in charge of one of the largest training schools for x-ray technicians, has presented his experiences in a book dealing with roentgenographic technique and the principles of its teaching.

In many respects this book is superior to the usual textbook of the kind available in this country, offering interesting variations from the ordinary. In other respects, however, it is deficient and somewhat disappointing.

Chapters covering the general principles of roentgenographic technique and the roentgenography of bones, joints, spine, and skull, by far the best in the book, are excellent.

Such important problems as the physical factors of the tube, the use of the correct focus spot, positioning, and tube-object distance are dealt with in a brief but comprehensive manner. The emphasis placed upon the importance of seemingly minor factors—proper film size, proper centering and correct markings, for example—is particularly laudable. Often these points which may be of decisive significance, especially when legal problems are involved, are neglected or presented without practical detail. A short chapter is devoted to the protection of the room, the patient, and the personnel. The need of choosing shutters and types of filtering, which may improve roentgenographic technique as well as serve as additional protective measures, is stressed.

Of considerable interest are the various ingenious gadgets, such as the oblique board, the curved bridge of Schoen, and a simple head rest, which are described and illustrated by photographs and sketches. The curved bridge, as demonstrated, is well adapted to the examination of joint spaces and affords a solution for various problems which may arise in the roentgenographic examination of the extremities. This device, rarely used in this country, should prove useful in delineating certain fine technical points.

The careful selection of illustrative photographs, sketches, and roentgenograms throughout the book gives the reader a clearer picture of a given procedure than many paragraphs of unbroken text. They make it possible for the student technician successfully to carry out the various techniques described.

In contrast to the excellence of these chapters, those having to do with the examination of the chest, the gastro-intestinal tract, and the genito-urinary tract appear sketchy and inadequate.

For each specific problem, the appropriate technical details regarding the type and size of films, the use of cassette or screen, and fixation are carefully described. The purely physical factors, such as kilovoltage, milliamperage, and time factors, however, are not discussed. This omission may be advantageous in that it avoids the confusion resulting from the many different factors inherent in each individual x-ray generator.

Schoen's book is to be recommended as an interesting and valuable addition to any library of roentgenology. It should prove particularly useful to those specializing in bone and joint roentgenography and should aid the roentgenologist in anticipating and being ready to meet the frequently difficult requests of the orthopaedic surgeon for unusual positioning.

INSTRUMENTS AND APPARATUS IN ORTHOPAEDIC SURGERY. E. J. Nangle, M.B., CH.B., F.R.C.S. Oxford, Blackwell Scientific Publications, 1951. 42 shillings.

This book is written as a complementary volume to other orthopaedic texts. It presents briefly information and technical details concerning appliances which have withstood the test of time at The Wingfield-Morris Hospital, Oxford, and The Royal National Orthopaedic Hospital in Stanmore, Great Britain.

Not only are details of the manufacture and the use of these appliances given, but also the principles involved in their use in such conditions as peripheral-nerve injuries and poliomyelitis. The author wisely limits his description to one or two examples of each type of appliance. Much valuable material is contained in the book's 222 pages and for the most part the illustrations are excellent. A wide variety of subjects is covered, ranging from plaster technique and the use of plastics in the construction of braces to the operation of a respirator. Of particular interest is the chapter on counter-weighted appliances, which make it possible for the patient in traction or plaster shells to mobilize himself to a considerable degree.

The book should be of real value to orthopaedists and particularly to those beginning their resident training.

ORTHOPAEDIC APPLIANCES ATLAS, Vol. I: Braces, Splints, Shoe Alterations. The American Academy of Orthopaedic Surgeons. Ann Arbor, Michigan, J. W. Edwards, 1952. $10.00.

This large and most worth-while volume was compiled and edited under the direction of a committee appointed by The American Academy of Orthopaedic Surgeons in cooperation with representatives from the Office of the Surgeon General, United States Army, and the Veterans Administration. It is lithoprinted, two columns to a page, in a format easy to read; it is beautifully illustrated with black and white photographs and line drawings.

The purpose of this book is to gather together in one atlas essential information concerning orthopaedic appliances for the orthotist, brace maker, and orthopaedic surgeon. It achieves this end in a most effective manner. The volume is divided into seven parts which deal with the history of orthopaedic appliances, the materials which are used in their manufacture, specific appliances for various parts of the body, and special apparatus used for poliomyelitis, paraplegia, and cerebral palsy, with a short section at the end on the measurement of joint motion and the measurements and tracings which a brace maker must have to make various appliances.

There are many contributors to this volume with a wide variety of training, including orthopaedic surgeons, metallurgists, experts on textiles and plastics from the National Bureau of Standards, engineers, representatives from industry, and many other sources. Their knowledge has been fused into a coordinated whole by the editors, producing a volume with a wealth of information which will be of great value to all concerned with the manufacture and fitting of orthopaedic appliances of all sorts.

This book represents a tremendous amount of work. All those who were concerned in its preparation are to be congratulated on the result. It is a much needed and valuable contribution to the orthopaedic literature.

LA PATOLOGIA DELLA SPALLA NEI LANCIATORE SPORTIVE. P. Graziadei ed A. A. Polacco. Bologna, Casa Editrice Licinio Capelli, 1951. L.1200.

The first two chapters are devoted to the anatomy of the shoulder and contain no new data. In the following chapter on the dynamics of the shoulder joint, the values given for forward flexion and abduction, are rather below those generally accepted. The value for concomitant movement of the shoulder girdle, however, tallies well with the prior observation of Fick and Strasser; so also do the diagrams made in the style of Lanz and Wachsmuth, presenting schemes of muscle synergism.

The real interest of the subject develops with the description of the throwing movement of the extremity which the author divides into three types: the usual overhead throw (javelin), the straight forward throw (shot put), and the "backhand" throw (discus).

The authors then proceed with the description of the muscle dynamics of the different types of throw and go into the motions in discus-throwing, shot-putting, hammer-throwing, tennis, baseball, polo, hockey, and some others.

The succeeding chapter is especially important for the orthopaedist, because it deals with the pathomechanics of injuries and the distinction between the acute and more chronic type of injury. The material is, however, rather scantily treated, and perfunctory allusions are made to constitutional articular lability and to endocrine, toxic, nervous, and other factors as predisposing elements.

The clinical side is treated more extensively. Muscle lacerations, especially those of the deltoid, of the short and long heads of the biceps (with characteristic signs), rupture of the biceps, and, of course, lesions of the rotator cuff (especially of the supraspinatus) come up for discussion. Nerve lesions, especially lesions of the nerve trunk, are briefly mentioned, as is the thrombosis of effort.

Of somewhat greater interest are the case reports in the following chapter, especially those of complete and incomplete avulsions of the greater tuberosity and traumatic osteochondritis dissecans of the shoulder.

The final chapter covers treatment. It follows the conventional technical lines, but the interesting part of it is the indications made. A wide place is accorded to conservative treatment, especially immobilization in cast and the use of novocain; operative interference is reserved for such conditions as massive avulsions or fractures of the greater tuberosity and for refractory cases which resist extensive conservative therapy.

The denervation of the joint by resection of the articular branches of the axillary and suprascapular nerves is mentioned and the technique of Tavernier is described and illustrated, but no personal experiences of the authors are reported.

This monograph is useful and is well organized; it constitutes a welcome addition to the kinetics of the shoulder, as well as to the clinical pathology of peri-articular lesions, so far as they arise from certain sports activities. It will be of equal interest to the surgeon and to the athletic coach.

EINFÜHRUNG IN DIE RÖNTGENOLOGIE. G. F. Haenisch, H. Holthusen, und A. Liechti. Stuttgart, Georg Thieme Verlag, 1951. DM 60.

The fifth edition of the *Einführung in die Röntgenologie* by Haenisch, Holthusen, and Liechti is now available in this country. The original purpose of the authors was to give graduate and postgraduate students of roentgenology an introductory view of the various roentgenological problems. The book in its present form, however, goes far beyond the scope of the beginner or student.

It is divided into three major parts. The first, dealing with the physical and technical background of roentgenology, was written by Liechti and is now revised by Fehr. The second part by Haenisch pertains to matters of diagnostic roentgenology; and the last, by Holthusen, deals with radiation therapy.

The first section encompasses not only the problems of equipment and electrical matters but also the physical properties and the character of radiation. Many of the accessories — shutters, filters, and kymographs, to mention only a few — so often omitted in textbooks, have been given attention and are well described.

Part II, diagnostic roentgenology, is interesting and covers many, but far from all, of the problems of this field. There tends to be an occasional overemphasis on functional and physiological matters which is rather typical of European, particularly of German, writers in contrast to the trend in this country to confine the text to anatomical observations. This emphasis on physiological rather than on anatomical questions detracts from the teaching value of the material and adds little of scientific or practical value.

Too much stress has been laid on unusual conditions rarely encountered by the average roentgenologist and too little on problems of greater importance and more frequent occurrence. Fractures and a multitude and variety of traumatic changes—for example, myelography for ruptured discs, problems concerning the demonstration of brain lesions, obstetrics, and many others—have been inadequately covered. This lack of appreciation of relative values reflects certain shortcomings in the practice of roentgenology which the reviewer had observed on a recent visit to Europe.

The organization and arrangement of material in this section are also open to criticism. It is difficult often to obtain a complete picture of a given problem, owing to the arrangement which divides normal and abnormal conditions of the same part of the body into widely separated chapters. The index, which should expedite the finding of desired information, is far from complete or satisfactory.

The section on therapeutic roentgenology is on the high level that is to be expected from one as distinguished as Holthusen. The chapters dealing with the theoretical and biological factors of radiation therapy are interesting and complete; and such problems as damage to the skin, growth, blood, and others are adequately covered. The fundamental ideas back of radiation therapy—its application and biological reactions to it—are well presented, but practical details of specific therapy are somewhat sketchy and could well be amplified. The critical evaluation of the literature on the subject of radiation therapy merits special commendation.

Despite certain drawbacks, this book contains a great deal of information which is of unquestioned value. The authors, whose reputation for clinical and scientific work is international, have given an excellent account of their experience, dating back to the early days of roentgenology; this is enriched by the tremendous amount of material which has been at their disposal. Excellent reproductions of roentgenograms, sketches, and diagrams accompany the text and enhance its value. *Einführung in die Röntgenologie* is recommended with certain reservations to the student or practitioner of roentgenology.

TEXT-BOOK OF ORTHOPAEDIC MEDICINE, VOL. II: TREATMENT BY MANIPULATION AND DEEP MASSAGE. James Cyriax, M.D., B.Ch.(Cantab.). New York, Paul B. Hoeber, Inc., 1951. $6.00.

The author explains that the fourth edition of this work is an amplification of previous editions and forms Volume II of a projected new work to be entitled *A Text-Book of Orthopaedic Medicine*. The present book is written for the physical therapist and explains the technical aspects of massage, manipulation, and passive exercise.

The text is well illustrated, particularly in showing the points for specific finger pressure in a variety of connective-tissue disorders in which therapists may be asked to apply massage. There is a brief summary of indications, warnings, and other details of technique on the page facing each illustration.

As a physician, one may question some of the indications for therapy described, but, as the book is written for therapists, no detailed discussion of indications of prescription or differential diagnosis is necessary.

The book is of value to physical therapists and as a reference for others interested in massage.

ETIOPATOGENESI DELLA DISPLASIA CONGENITA DELL' ANCA. L. Giuntini. Bologna, Casa Editrice Licinio Cappelli, 1951.

The distinguishing feature of this monograph which is devoted entirely to the study of the etiology and pathogenesis of congenital dislocation of the hip is the approach to the problem from the anthropometric point of view. For instance, in introducing the so-called "sacro-cotyloid angle" into the problem, the author establishes what he calls the orthogonality of the femoropelvic as well as of the femorocalcaneal relationship and presents with it all sexual and ethnic variations. The chapter on the embryogenesis of the hip then deals directly with the problems of femoral torsion and acetabular inclination in more or less conventional fashion. The succeeding chapter on the pathological features of dysplasia of the hip follows, more or less, the lines of the classical observers, such as Putti and others.

The chapter on genetic factors contains a number of interesting concepts, all more or less conjectural, such as the theories of dysplastic diathesis, of endocrine influences, and of vitamin deficiencies, recording the

opinions of preceding observers and adding an interesting observation of de Rosa on congenital dislocation of the hip in the rabbit.

In the line of etiopathology of the congenital dislocation of the hip, the author follows the opinion of Le Damany, whom he credits with the recognition that the acetabular cavity in its formation is an adaptation to the position and mobility of the femoral head and that the anteversion of the femoral neck is an unfavorable element for the containment of the head in the socket.

He believes, however, that anteversion is useful morphologically, because it maintains the above mentioned orthogonality with the weight-bearing sacrocotyloid axis and furnishes a better lever arm for the pelvitrochanteric muscles.

On the other hand he does not subscribe to the mechanical theory of coxal dysplasia regarding the extrauterine position of the foetus (Störck), nor does he subscribe to that of the failure of the head and neck to follow the inward rotation of the shaft (a theory propounded first by von Friedländer many years ago). He does not accept Badgley's view, who believes that the synchronism between the different parts in which the spontaneous rotation of the entire lower extremity should take place is disturbed.

In fact, not accepting any one of the mechanical theories, the author is inclined to advance a plurality of etiological factors, emphasizing that congenital dysplasia, which manifests itself by various clinical syndromes, has also a number of different etiological causes. In rare cases it presents itself as a teratological deformity due to an antenatal condition.

More often it is considered a phenomenon of anthropological dysplasia, almost exclusive in the white race. It may be due to anomalies in muscle attachment or to muscle disease in the foetus, although he concedes that in a majority of cases it is of endogenous origin and is brought about by a primary deficiency of the pelvifemoral congruency. One of his opinions is that the primary defect is not an arrest or a retardation of development, but a true disharmony between pelvis and femur, in which excessive anteversion constitutes the principal feature.

The book has been manifestly prepared with a great deal of care and with an exhaustive study of the literature, as evidenced by the imposing bibliography appended. It is well worth reading and of considerable interest to the student of congenital dislocation of the hip.

A Textbook of Medical Conditions for Physiotherapists. By Joan E. Cash, B.A., M.C.S.P. Philadelphia, J. B. Lippincott Company, 1951. $5.00.

This text for physical therapists serves as an interpretation of diseases in terms of reaction to physical medicine procedures to meet the needs of the technician. Neuromuscular lesions and the arthritides properly constitute the bulk of the discussion, although the diseases of the cardiovascular system, disorders of the abdominal viscera, and common skin lesions are also covered. The only surgical conditions included are thoracic, as more emphasis is placed on preoperative and postoperative exercises in English hospitals than in most American hospitals.

This is a valuable book for those concerned with the training of physical therapists and may well serve as a standard reference for the physician lecturing on medical topics to student therapists.

Das Klapp'sche Kriechverfahren. Dr. Bernhard Klapp, unter Mitarbeit von Ella Biederbeck und Ingeborg Hess. Stuttgart, Georg Thieme, 1952. DM 11.70.

The system of Rudolf Klapp has been in use among German physical therapists for forty-six years. Based on what the author calls the "orthogenetic-degenerative" concept of scoliosis and other deformities of the spine, his method represents an attempt at correction primarily by a return to the horizontal position. It had been Klapp's aim to found institutions in which the patient would temporarily return entirely to the "four-footed horizontal mode of life."

Aside from a discussion of the general concepts on which it is based, this little book consists of specific exercises, with excellent illustrations and a brief discussion of the method and indications in each case. The emphasis appears to lie mostly on all forms of scoliosis. However, many of these exercises are also indicated for post-poliomyelitic deformities, such as lordosis, kyphosis, and torticollis, and in certain cases are indicated after fractures of the vertebrae and tuberculosis of the spine. Prophylactic aims, such as strengthening the pectoral muscles, are also stressed. Most of the exercises can be performed at home, without special equipment other than protective pads for knees and hands.

Despite its somewhat ardent, over-zealous tone, this pamphlet is recommended as an important addition to the literature on prophylactic posture exercises and on problems of rehabilitation.

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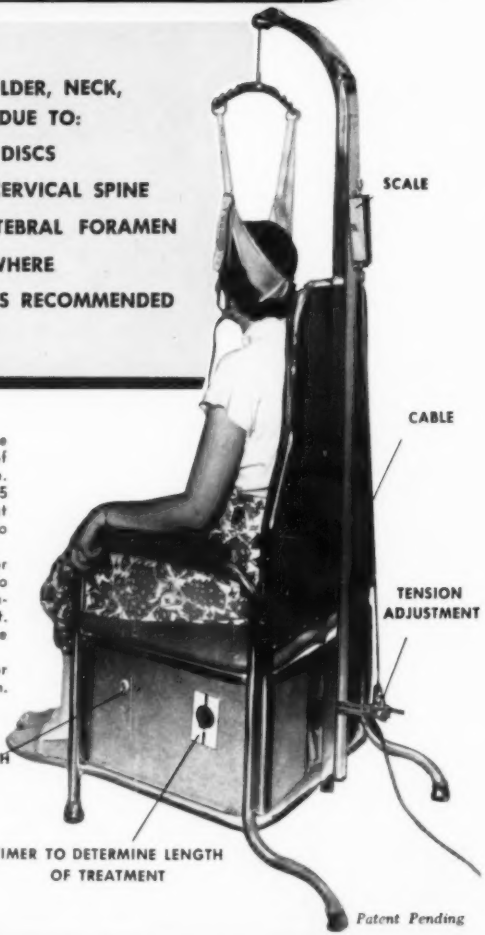

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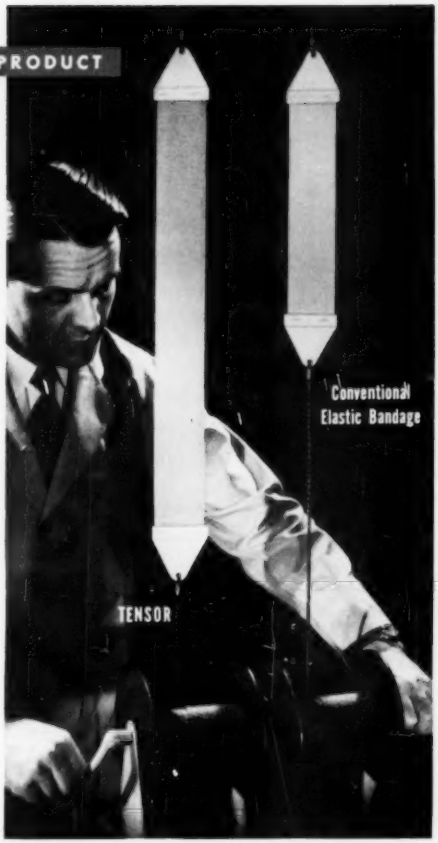

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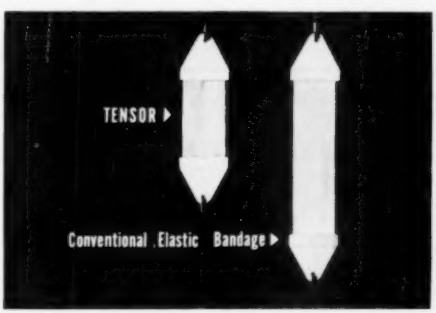

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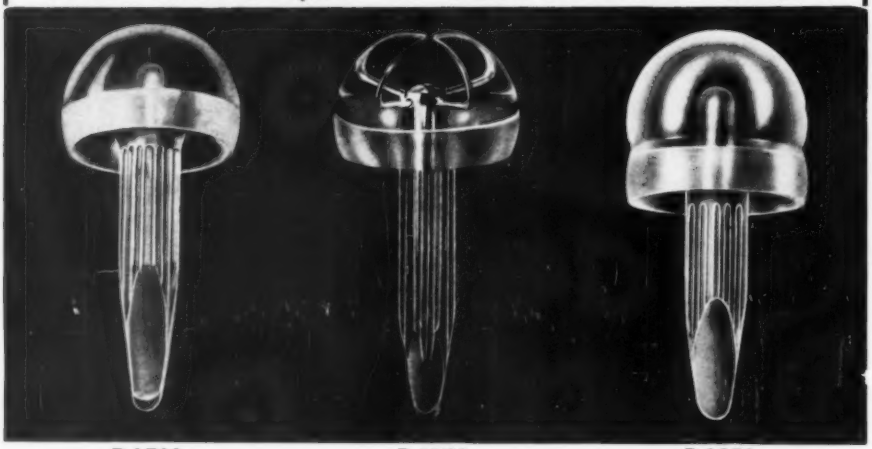

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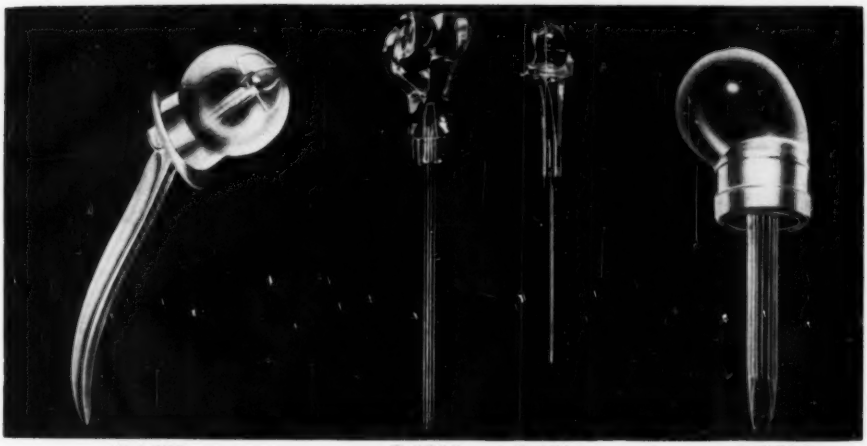

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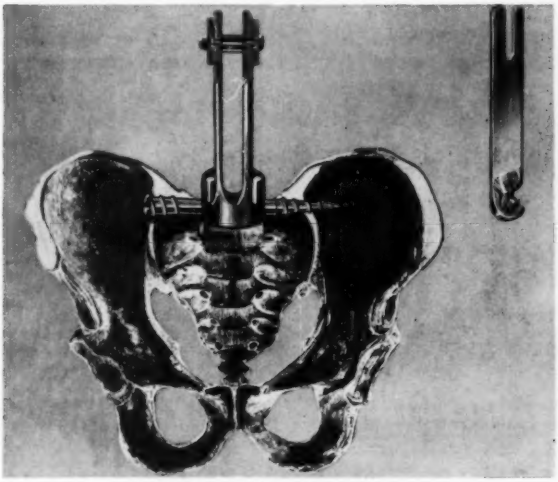

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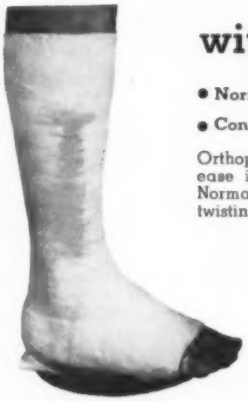

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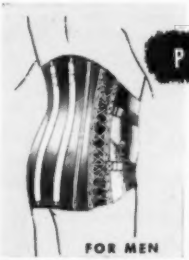

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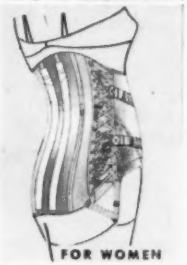

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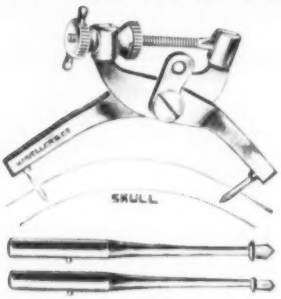

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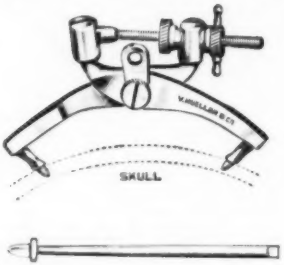

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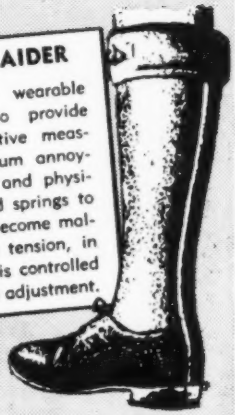

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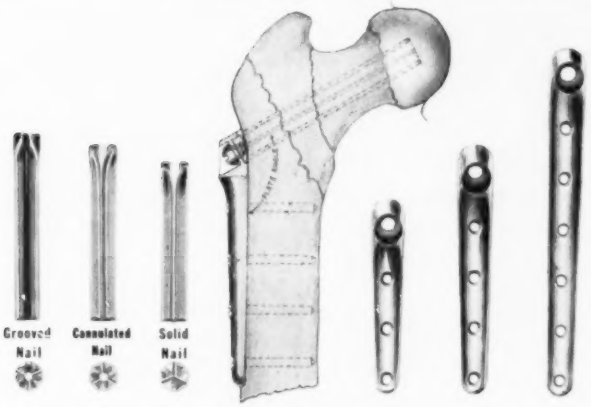

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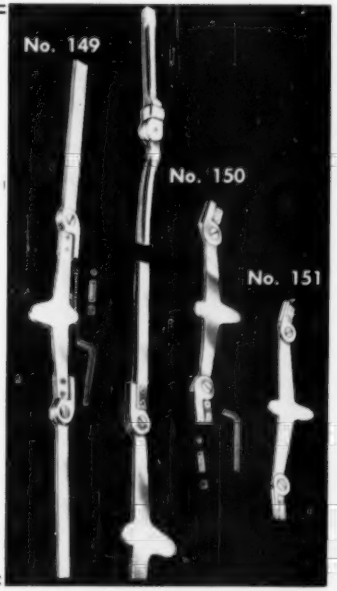

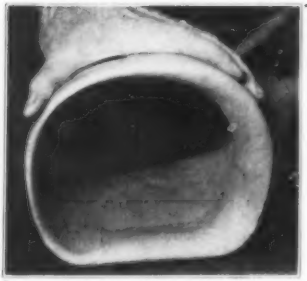

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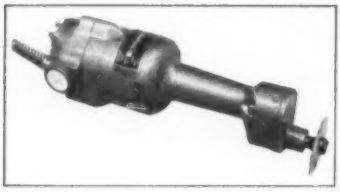

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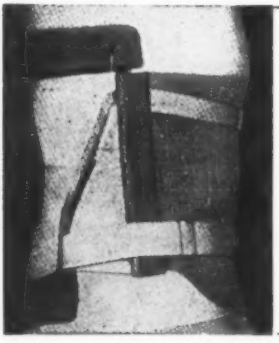

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